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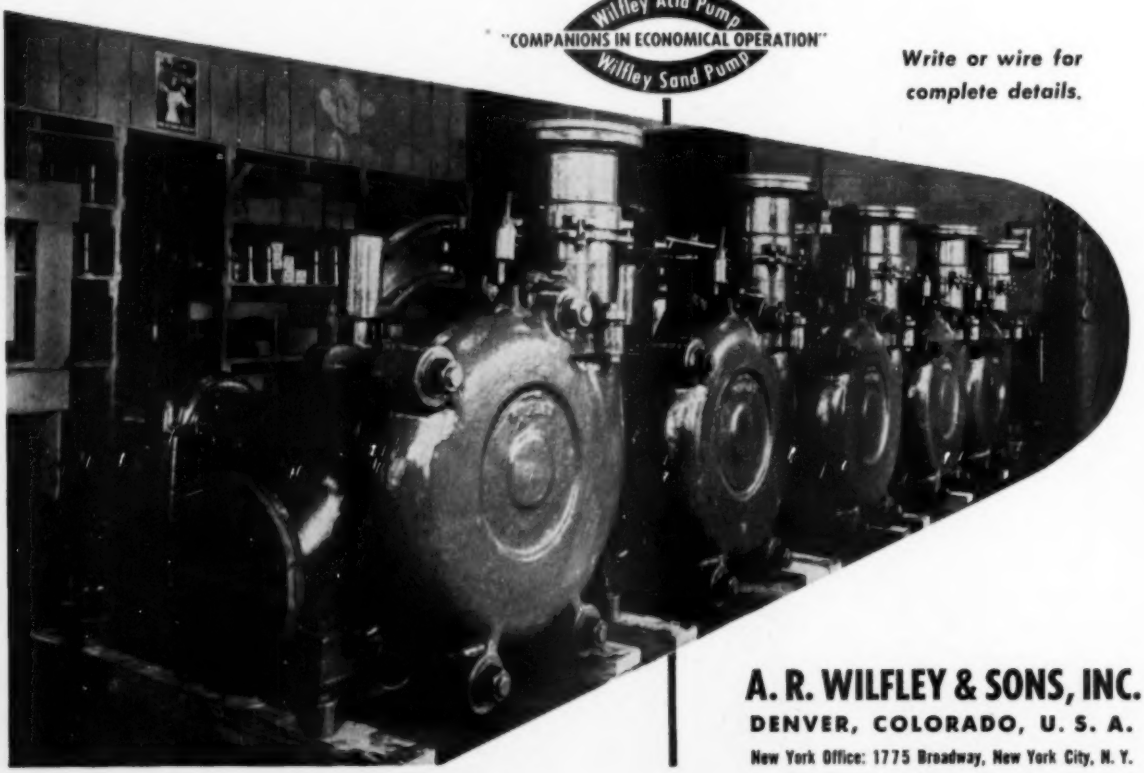

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MINING engineering

VOL. 6 NO. 9 SEPTEMBER 1954

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COVER

Patterns of holes, such as cover artist Herb McClure selected, that will move rock when properly loaded, are the endpoint of the drilling cycle. But the starting point—the equipment that puts those holes down—weighs large in the cost sheet of itself. For the latest trends in making small holes to make big ones, turn to the series of articles beginning on page 886.

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— Personnel Service —

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

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Geologist, 23, B.A. in geology, married with family. Desires employment in northern or western U. S. Now employed in unrelated field. M-96.

Mining Engineer, 28, B.S., M.S., in mining engineering, registered professional engineer. Good scholastic record. Three years experience coal preparation and iron ore beneficiation work. Desires permanent responsible position in ore beneficiation, preferably in East or Midwest. Currently employed; available reasonable notice. M-97.

Manager, or Assistant. Mining Engineer, 40, married, three children. Broad experience all phases exploration, development, operation, and administration with large mining companies in South America since 1936. Reliable organizer and producer. Versatile engineering designer. Fluent Spanish. M-99.

Coal Preparation Engineer, 44, married, with family, B.S. in mining engineering, University of Illinois. Eighteen years experience all phases of preparation; especially well qualified in maintenance and operation. Registered professional engineer, Pennsylvania. Excellent record and references. Desires executive or managerial position with progressive company. M-98.

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Mining Engineer, with a broad knowledge of coal mining; must be thoroughly acquainted with coal geology and be experienced both in coal stripping and underground coal mining. Must be able to give technical advice on improving the mining operations of the company's actual mines, to orient the prospecting and starting of new coal mines in the same region, and be familiar with the primary beneficiation of the improvement and mechanization of the underground mines. Must have a broad knowledge of modern mechanical mining equipment and experience in directing the operation of a reasonably large modern coal mine. Company provides the best living quarters available. For man and wife only. Salary, $15,000 a year. Location, South America. F304.

Mining Geophysicists, 2, to take part in pioneer geophysical exploration, and development program. Good background in physics and electronics essential. Location, West. W290.

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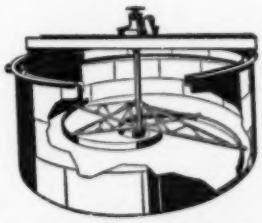
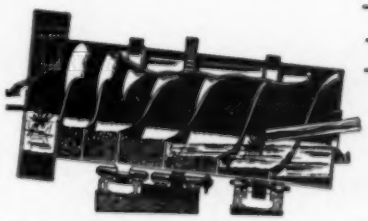


"AUTO-RAISE" THICKENER

One of the distinctive features of Hardinge Thickeners is the "Auto-Raise" driving mechanism, which automatically lifts the scraper away from an overload or obstruction in the tank bottom—eliminating costly breakdowns and delays. Another optional feature is the double-spiral scraper which removes settled solids from the tank bottom in one revolution. Bulletin 31-D-2.



COUNTER-CURRENT CLASSIFIER

The unique "spiral-squeeze" action of the Hardinge Counter-Current Classifier literally wrings the dirty water and fines from the sands—producing a cleaner, more uniform oversize—nearly dry, if desired. Highly efficient when used in closed circuit wet grinding with a mill, this classifier returns the oversize to the mill for further grinding and discharges a product as fine as minus 200 mesh, if desired. Bulletin 39-B-2.

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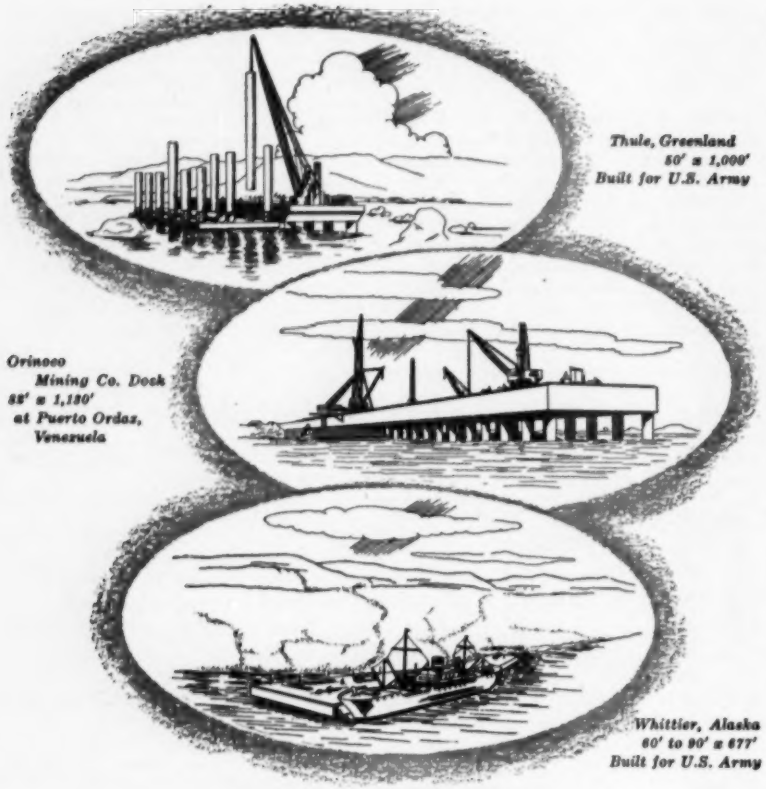

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—Letters to the Editor—

Comment on Yugoslavia

As an Old Balkan Hand I was delighted to read the article: *Yugoslavia—Potential Mineral Giant* (MINING ENGINEERING, May 1954). I have for many years been intensely interested in the Balkans, but the events following World War II, which have put Rumania, Hungary, and Bulgaria out-of-bounds, have not dampened my enthusiasm for them. I have just returned from a six weeks trip to Yugoslavia, and it is at this point I must part with your article, since it contains information that I have not been able to check.

In particular, I think the statement that Yugoslavia has extensive iron ore should be verified, as I rather believe the contrary may be the case.

With regard to the copper production, I must say the figures refer probably to ore and not to the metal, as the statement on page 493 might lead one to expect. "Only 983,000 tons" is, of course, tremendously high production, the actual being nearer 38,000 to 40,000 tons of refined copper.

It is a pity that the caption under the photograph of the Trepca mine calls this the biggest copper mine producer. Trepca, of course, is a very important lead and zinc producer, which from all reports has a long and useful life ahead of it.

J. D. Grothe
Vice President
The Dorr Co.

We can only go along with Mr. Grothe's extensive knowledge of Yugoslavia. With respect to iron ore, the statement that reserves are extensive should be modified in the light that the tonnages reported are small in comparison to those of the major iron and steel producing nations, and that the ores are comparatively low grade. One source considered them extensive, "in contrast to the size of the nation's industry."

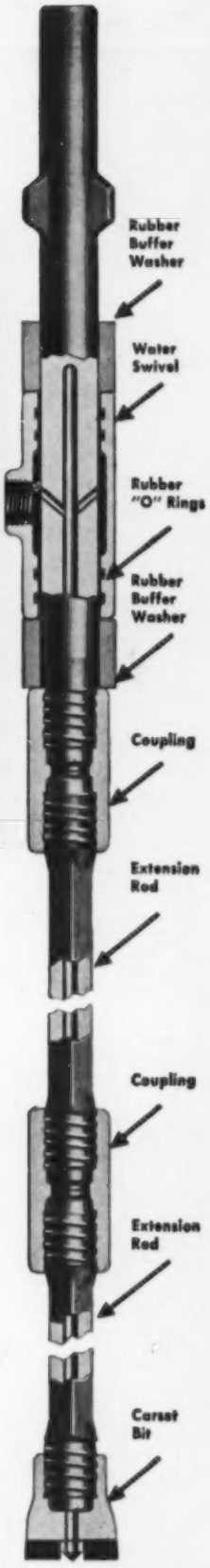
The crucial word ore *was omitted after the phrase "copper production" in the text on page 493. The figures are correctly listed as copper ore production in the table on page 491.*

Due to the unfamiliarity of the scenes the information in the caption for the photograph on page 492 actually applies to Bor, and Mr. Grothe has kindly supplied the correct caption for Trepca in his letter. —Ed.

Uranium and Gold

While not properly "Letters to the Editor," inquiries from nonmembers are a big part of the daily mail. Interesting, but not surprising, uranium exploration and investment is current top subject by about 3 to 1—but gold still has its lure, running in second place for interest.—Ed.

make short work of
LONG HOLE DRILLING



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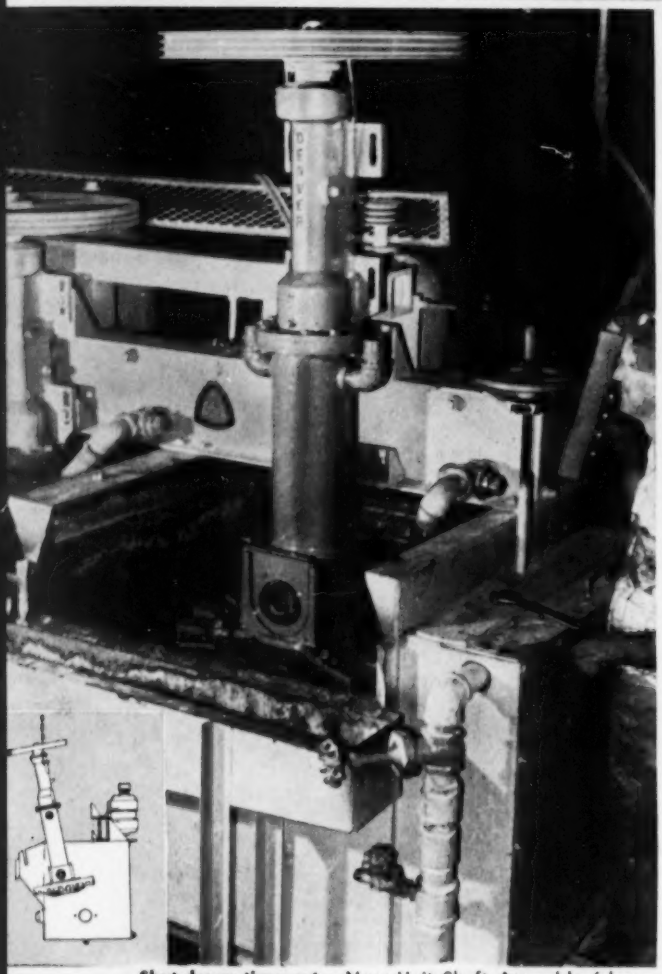

Shut-down time cut — New Unit Shaft Assembly (above, being lifted out) on Denver "Sub-A" Flotation Machine cuts down-time to 10 minutes when replacing wearing parts. Only four easy-to-reach bolts on upper spindle bearing to remove and unit can be easily pulled out. It is applicable to all older machines because of DECO's standardization and policy of "no yearly models, but constant improving." Simplicity and standardization is our goal. Item No. 301.

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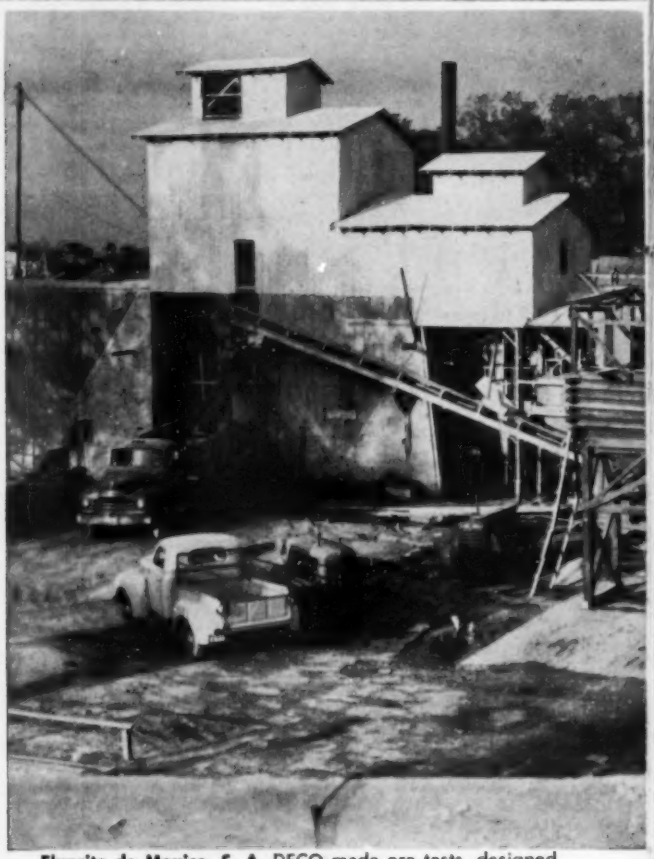

Fluorita de Mexico, S. A. DECO made ore tests, designed flowsheet, made preliminary mill drawings and supplied equipment for this new fluorspar mill. DECO engineers are

Thickener eliminated by 1½" Denver Vertical Pump's ability to handle frothy zinc concentrates without excessive spray water. Item No. 304.

Mr. Clarence Thom, Director of Denver Ore Testing Division: "We have helped operators around the world increase profits by checking mill results. May we help you?" Item No. 306.

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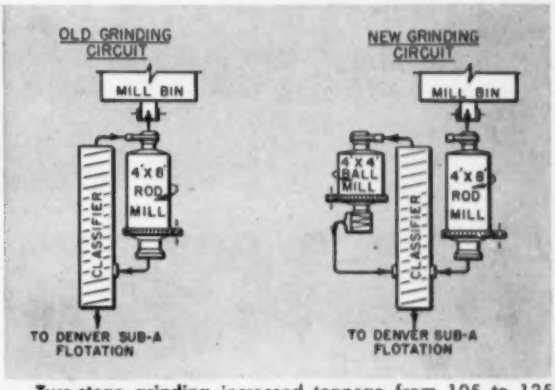
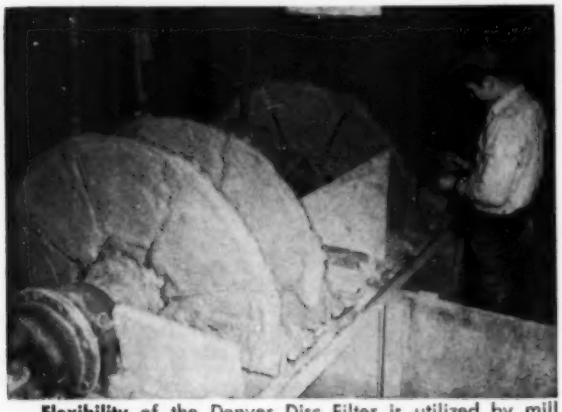
IN THE NEWS . . .

daily helping mill operators increase production and recovery! Let us help you on your next flowsheet change. Write for the complete Fluorita story. Item No. 310.

All-Steel Heads on all Denver Ball Mills put strength where it's needed. Item No. 308.

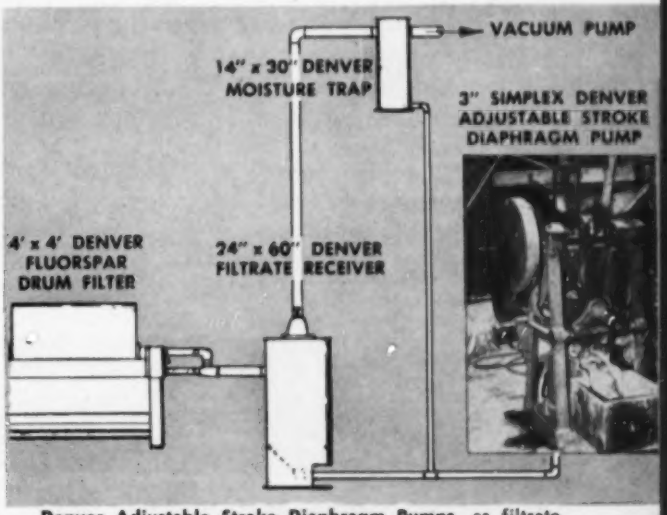


Two-stage grinding increased tonnage from 105 to 135 T/24 hrs. New DECO Flowsheet Study compares cost, H.P., savings, etc. on one- and two-stage systems. Item No. 302.



Flexibility of the Denver Disc Filter is utilized by mill operator to filter zinc on two discs and lead on one disc. Item No. 307.

New handy reference on Denver Tanks has just been published. This Denver Tank Bulletin includes specifications, price estimates, applications, and erection data. Item No. 305.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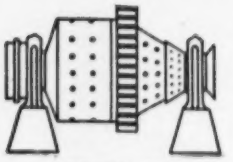

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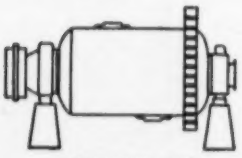
TUBE MILLS



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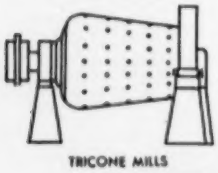

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When you use CF&I Grinding Balls you'll get even wear, resistance to impact and high through-put. Special treatment and controlled analysis steel assure high hardness rating with the necessary toughness to give maximum service in all sizes and types of grinding mills operating at either high or low speeds.

CF&I Grinding Balls are carefully forged and inspected to assure long life—are free of surface pits, circumferential ridges and other surface unevenness.

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Magnetic Variometers of the Schmidt Type, Their full use and maintenance illustrated by Hilger & Watts variometers, by J. McG. Bruckshaw, *Hilger & Watts Ltd.*, London, available in U. S. from Jarrell Ash Co., $4.50, 115 pp., 1954.—The author, reader in geophysics, Imperial College, has been associated with geophysical prospecting for more than 20 years and has a wide experience in field surveying with magnetic variometers. Although this handbook is illustrated with details of Hilger & Watts variometers, the author says that, in general, all the initial and routine adjustments described are incorporated in other designs.

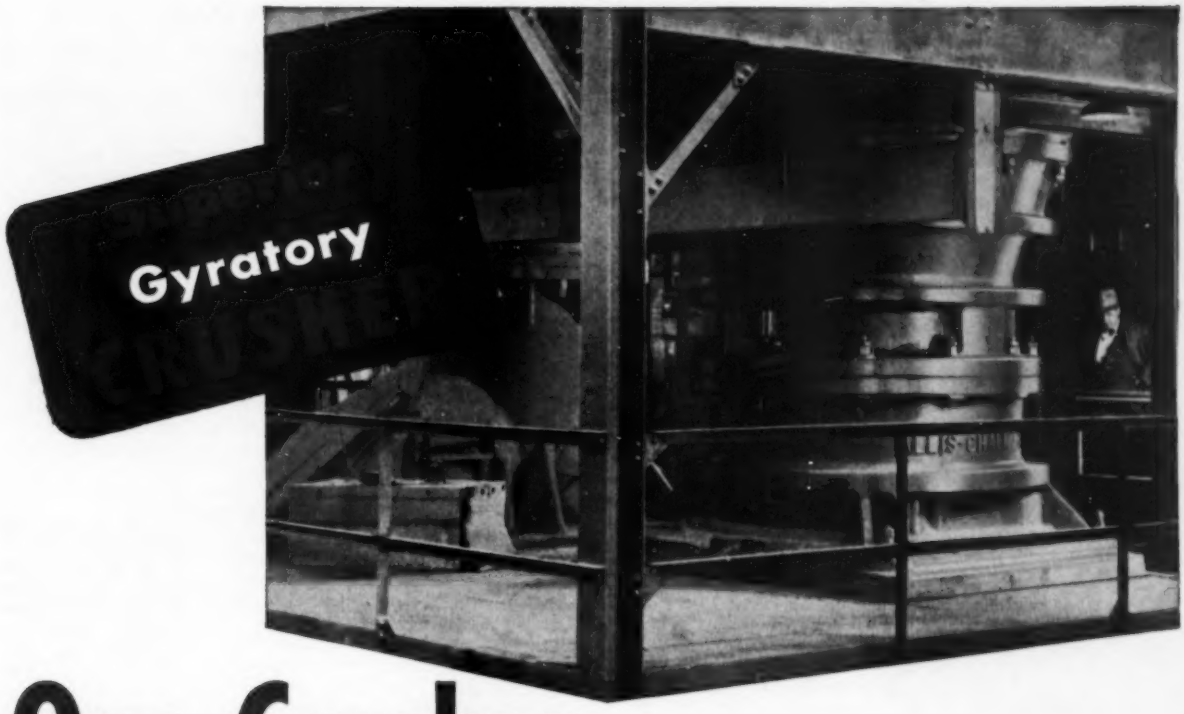
Engineers' Dreams, by Willy Ley, *Viking Press*, $3.50, 239 pp., 1954.—Nine projects that could be accomplished if it were not for political and economic difficulties. These projects include: a tunnel under the English Channel, "seadromes," harnessing volcanoes and hot springs, creating a lake in the Congo Basin, shrinking the Mediterranean by building a dam at the Strait of Gibraltar, and obtaining power from the sun, waves, and wind.

The Sulphur Data Book, compiled by technical staff, Freeport Sulphur Co., edited by William N. Tuller, *McGraw-Hill Book Company Inc.*, $5.00, 143 pp., 1954.—The best available data in convenient form for the engineer and chemist using sulphur. Five sections cover nature of sulphur, physical and chemical properties, reaction thermodynamics, solubility, and analysis. Sulphuric acid conversion tables and a selected bibliography are included.

Collective Agreements on Time and Motion Study, by G. Jay Anyon, *Society for Advancement of Management*, $4.50, 1954.—Based on contract research from 1946 to the present, this handbook for industrial relations heads, union officials, legal counsel, production managers, industrial engineers, and foremen points out areas of misunderstanding and protracted argument over time and motion study. Solutions are shown for both management and labor.

Diesel Engine Catalog, Vol. 19, 1954-1955, edited and published by Rex W. Wadman, *Diesel Engines Inc.*, Los Angeles, $10.00, 390 pp.—Details of engines and auxiliary equipment produced by major manufacturers. Designs and developments of the past year have been added to this edition and the accessories section has been expanded.

(Continued on page 858)



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ALLIS-CHALMERS EXHIBIT
at the American Metal Mining Exposition...
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HOMESTAKE MINING Company installed a modern 30-55 *Superior* gyratory crusher to replace two old *Gates* gyratories. Despite the fact that the new crusher has a 30-inch feed opening, instead of a 17-inch opening as on the old crushers, it fits snugly into half the former space for two. The *Superior* can turn out much more tonnage than both old crushers. And it's built to surpass the 38-year service record of the old crushers.*

This increased capacity and improved performance is a direct result of over 70 years of experience in building crushers, years in which Allis-Chalmers leadership introduced many design advantages in gyratory crushers — the short mainshaft . . . improvements in the shape and size of the crushing chamber, in weight distribution, in dust protection and lubrication. These and other features mean more *profitable* crushing for you, when you specify Allis-Chalmers!

**Yes, the old* Gates *crushers were built by Allis-Chalmers too — back in 1913!*

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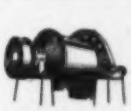
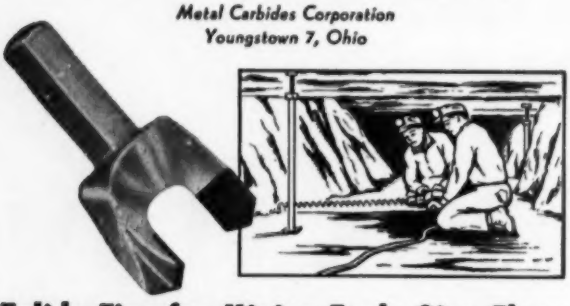

Grinding Mills

Kilns, Coolers, Dryers

● Mining contractors, ore prospectors, coal operators and construction firms are realizing tremendous savings by taking advantage of our **exclusive fabrication service!** Contractors send us the necessary diamond stones from their own stocks—we hand set them in a super-hard tungsten carbide crown and braze to the threaded steel blank. Hand-set bits assure the proper positioning of each diamond stone to achieve maximum cutting efficiency. The carbide matrix holds the diamond stones until entirely used up. These advantages mean lower drilling costs to you. We can also supply complete core bits or salvage the stones from used bits at nominal cost. Supplied in standard sizes EX, EXE, AX, BX, NX, etc.

Metal Carbides Corporation
Youngstown 7, Ohio



Talide Tips for Mining Tools Give These 3 BIG ADVANTAGES . . .

1. EXTRA STRONG
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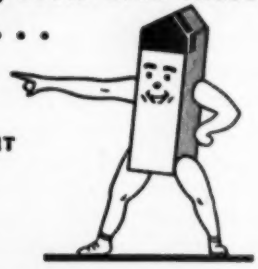
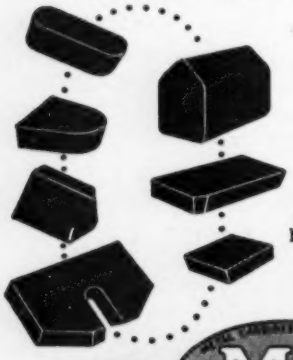
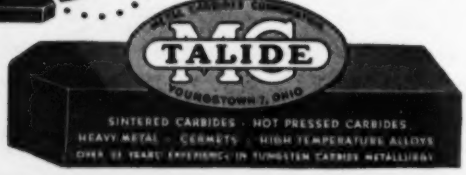




● A complete line of low-cost, high-quality Talide Tips is offered fabricators and users for tipping machine bits, rock bits, drill bits, roof bits and open-pit bits. All Talide Tips have a special surface finish that facilitates brazing. Non-standard shapes and sizes quoted on request.



Books for Engineers

(Continued from page 856)

Geology of India, by D. N. Wadia, *Macmillan & Co. Ltd.*, London, available in the U. S. from St. Martin's Press, $10.00, 3rd ed., 531 pp., 1953.—This textbook for college students summarizes the main facts of the physical features, historical and economical geology, and physiography of India, with some reference to Pakistan, Burma, Ceylon, and Tibet. Some sections have been rewritten and the whole text has been revised in detail. References.

An Introduction to the Design of Underground Openings for Defense, Colorado School of Mines Quarterly, Vol. 46, No. 1, *Dept. of Publications, Colorado School of Mines,* $3.00, 304 pp., 115 ills, 23 tables.—Each chapter is by a different author and such specific phases of the subject are discussed as: protection standards, rock pressure problems, rock tunneling, a method for determining of stresses around an opening under impact loads, heating, ventilation, and air conditioning. A complete subject bibliography is given.

Coal Mine Modernization, 1954, *American Mining Congress,* $3.00, special rate of $2.75 per copy on orders for 10 or more copies.—Useful information on methods, operating practices, and equipment for efficient coal production and preparation. The book contains all the papers and discussions of the 1954 Coal Convention held in Cincinnati, May 3 to 5, 1954. Fully illustrated.

Keystone Coal Buyers Manual, 1954, *McGraw-Hill Publishing Co.,* $25.00, 726 pp.—"The Coalman's Bible" contains listings of all active coal mines with an annual production of 50,000 tons or over. Given are trade names; river transportation; description of seams, with burning characteristics of coal from each seam; index of operators producing from any seam; mechanical cleaning plants with details on equipment, sizes washed, etc.; sales companies; information on 1892 mines in the U. S. and Canada, including mining, haulage, and electrical data. The mines directory section contains 1444 companies, lists officials, operating personnel, mine life expectancy, tonnages, etc., and this section, the *Coal Mine Directory,* may be purchased separately for $15.00.

Ferromagnetic Domains, by K. H. Stewart, *Cambridge University Press,* $4.75, 176 pp., 1954.—An outline of the fundamentals of domain behavior: magnetocrystalline anisotropy, magnetostriction, domain arrangement and walls, hindrances to domain wall movements, time effects, and magnetic and thermal energy changers.

Monomolecular Layers, edited by Harry Sobotka, *American Assn. for the Advancement of Science,* $4.25, 207 pp., 1954.—A cross-section of the recent progress in monomolecular layers. Far from attempting a comprehensive treatment, the contributors hope to assemble a symposium that will illustrate the scope and strength of their methods and techniques and will direct the reader to more detailed publications.

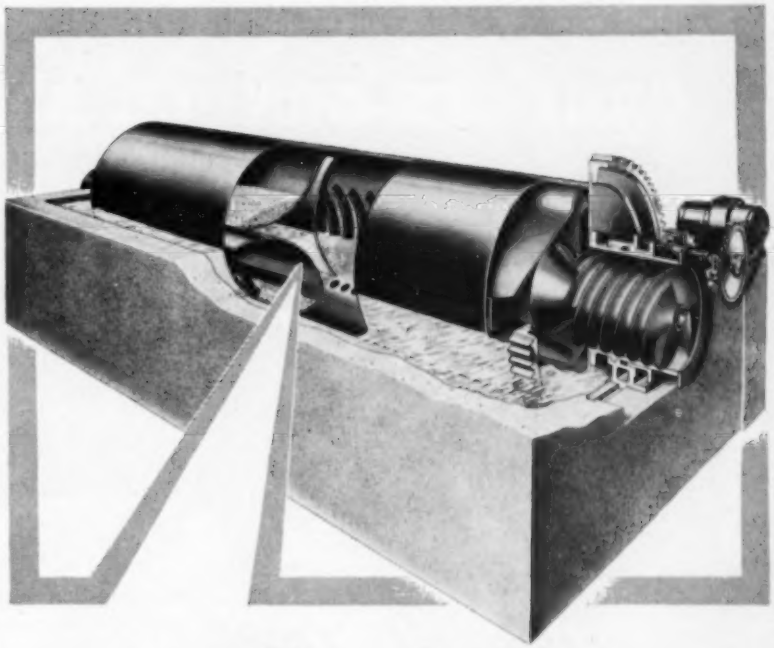
Techniques of Plant Maintenance and Engineering—1954, *Clapp & Poliak Inc.,* $7.50, 291 pp., 1954.—Proceedings of the Fifth Plant Maintenance and Engineering Conference, held concurrently with the 1954 National Plant Maintenance and Engineering Show in Chicago. Included are all the prepared papers, complete transcripts of the questions and answers that followed them, and summaries of the 20 round table discussions at which smaller groups discussed special problems.

Please Order the Books Listed Below from the Publishers

Geology of the Thoreau Quadrangle, McKinley and Valencia Counties, New Mexico, by Clay T. Smith, Bulletin 31, *State Bureau of Mines & Mineral Resources, New Mexico Institute of Mining & Technology,* Campus Station, Socorro, N. M., $1.00, 40 pp.—Structure, stratigraphy, and mineral and groundwater resources of a part of the northeast flank of the Zuni Mountains, about 15 miles west of Grants, N. M. In addition to its reported uranium deposits this area is critical to petroleum exploration in the San Juan Basin, because rocks exposed there are of the same formation that underlie the basin. The author is head of the dept. of geology, NMIMT, and research was carried out cooperatively by NMIMT and California Institute of Technology. The report is accompanied by a 3-color map showing all formations that are potentially productive of uranium. This map, 21x27 in., may be purchased separately for 75¢.

Mining Directory of Minnesota, 1954, by Henry H. Wade and Mildred R. Alm, *Mines Experiment Station,* University of Minnesota, Minneapolis, 34th ed., $1.00, 274 pp.,—A list of all operating companies and major holding organizations indentified with Minnesota iron ranges, together with officials, subsidiary and affiliated companies, as well as pertinent information, general statistics, and maps.

Proceedings of the Third Annual Water Symposium on Water Pollution, Dec. 14 to 15, 1953, Bulletin No. 43, *Engineering Experiment Station, Louisiana State University,* Baton Rouge, La., 50¢ (No stamps, please.)



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—ON FASTER COOLING, MINIMUM FLOOR SPACE AND DRIVE POWER

The **STEARNS-ROGER IMPROVED CALCINE COOLER** uses internal cells which approximately double the cooling surface—taking full advantage of the economy of water cooling both by conduction and evaporation.

Pre-determined cooling. Special flights or lifters on the slowly revolving cylinder advance the hot material thru the proper length of Cooler to obtain the desired temperature.

Low power requirements. Water level is regulated so Cooler and its load virtually float. Minimized weight, plus suitable trunnion bearings, reduce friction and power needs.

Protection of shell. Even in case of shut down with a hot load, shell is protected by its cooling water jacket.

Continuous feed. *Minimum dust loss. Can be sealed* against contaminating atmosphere.

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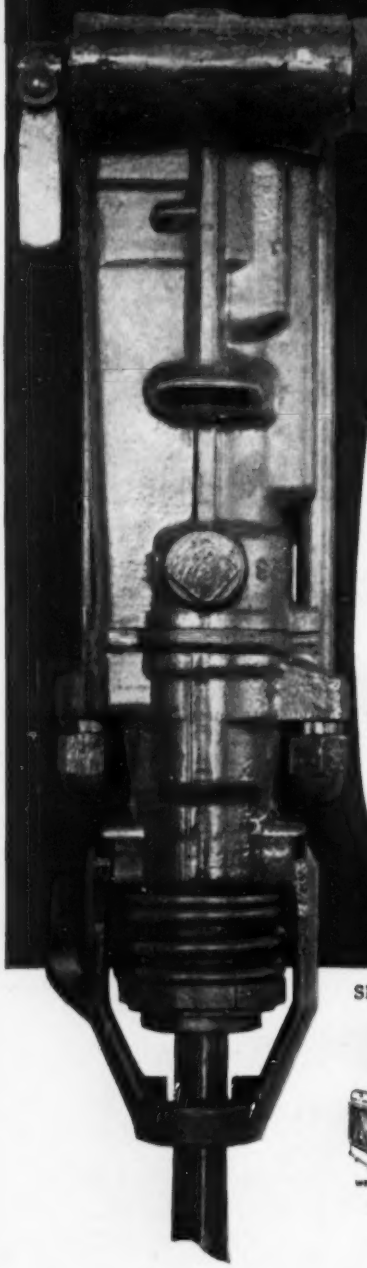
THE STEARNS-ROGER MFG. CO. DENVER, COLORADO

GARDNER-DENVER ANNOUNCES

THE NEW S58 SINKER!



new! the medium-weight sinker that's quickly changed from wet to dry . . . to automatic wet.

new! automatic valve for fast drilling . . . easy holding.

new! full swiveling water connection.

new! large-area water screen and self-cleaning air system.

new! steel puller easily operated . . . simple to maintain.

The NEW MODEL S58 is a brother to the famous GARDNER-DENVER S48— the lightweight sinker that's already a favorite for fast, low-cost drilling.

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THE QUALITY LEADER IN COMPRESSORS, PUMPS AND ROCK DRILLS FOR CONSTRUCTION, MINING, PETROLEUM AND GENERAL INDUSTRY

Gardner-Denver Company, Quincy, Illinois

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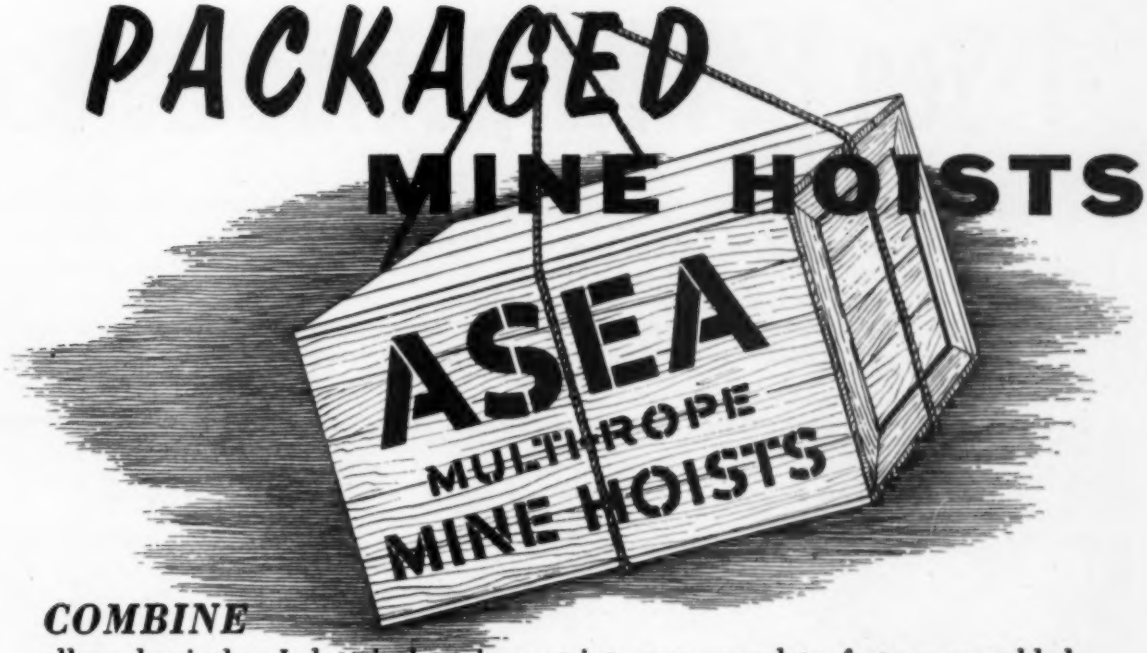
PACKAGED MINE HOISTS



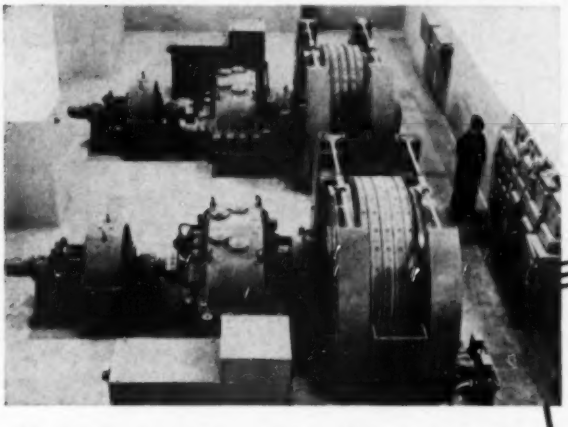
COMBINE
all mechanical and electrical equipment into one, complete, factory-assembled and guaranteed hoisting plant package.

COMBINE **unique** *safety* **of operation, due to load-dividing parallel ropes, positive protection against damage from over-winds, and patented electric speed guards with** *flexibility* **through fingertip "switch-over" choice between fully automatic, push-button, or manual control for hoisting from any one of a number of levels.**

COMBINE **hoisting** *capacity* **up to the largest yet to be installed in any mine with** *small space requirements*—**small enough to allow hoists to be installed in headframes.**

COMBINE *saving in first costs* **of hoisting equipment, foundations, lifting facilities, hoist housings and headframes with** *reduction in operational costs* **due to less rope wear, lower power demand, fewer or no operators and less maintenance.**

These two ASEA mine hoists with four parallel ropes are among those mounted above the shaft



Take advantage of ASEA's 20 years of experience in developing these complete hoist installations. Let us send you our introductory bulletin with more information about the ASEA hoists, or if you have any plans for new hoisting facilities let us talk them over with you.

AROS ELECTRIC, INC.

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NEW YORK 21, N. Y.

COUPON

AROS ELECTRIC, INC.
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Please send me your free introductory bulletin on the ASEA multi-rope mine hoists.

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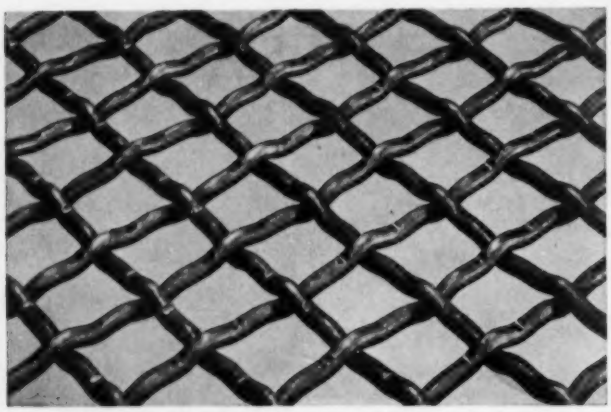
See Hewitt-Robins at San

Learn How Hewitt-Robins Can Help Solve Your Bulk Materials Handling Problems, Large or Small

Hewitt-Robins is the only company that designs and manufactures a complete line of equipment for handling and processing solids, liquids and gases in bulk.

We specialize in vibrating equipment to screen, feed or shakeout material—belt conveyor systems (both belting *and* machinery) to convey solids in bulk—hose to handle liquids or gases.

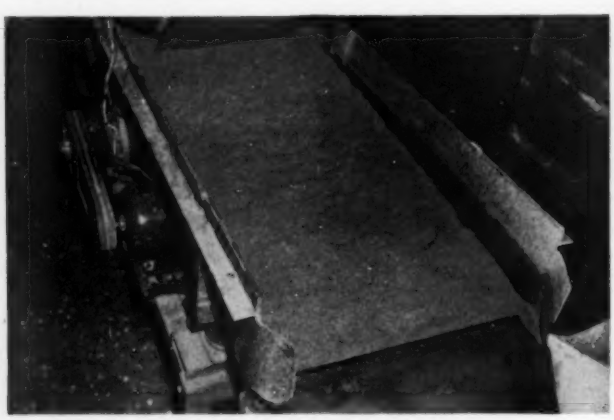
Throughout the world, Hewitt-Robins equipment and complete systems are setting new records for safe,



Screen Cloth. Hewitt-Robins screen cloth is specially engineered to accurately size large tonnages and cut screening costs . . . utilizing a full range of metallic wire to meet individual job requirements . . . available in standard production size openings from 3/16" and coarser; wire sizes from .105" up to and including 1" diameter.

Belt Conveyors. Hewitt-Robins designs and manufactures a complete line of belt conveyor systems engineered to meet the specific requirements of particular jobs . . . Belting, conveyor machinery and component parts are readily available from standard "on-the-shelf" stock, and are guaranteed to provide top conveyor performance.

Vibrating Screens. Hewitt-Robins manufactures four types of economical vibrating screens: . . . Gyrex® positive stroke 4-bearing screens; Eliptex® horizontal operating flat screens; Vibrex® full-floating, unbalanced pulley-type 2-bearing screens and the Eliptex Dewaterizer having specially designed Eliptex screen with micron-size opening stainless steel flat rod deck.



Vibrating Feeders and Conveyors. Fully mechanical, high capacity—low power consumption vibrating feeders easily maintained by your own personnel. Continuously balanced vibrating conveyors now available in longer units with higher capacities at lower horsepower. Handle a wide range of materials—wet or dry, lump or pulverized, packaged or loose, hot or cold, abrasive or corrosive.

HEWITT-ROBINS

EXECUTIVE OFFICES, STAMFORD, CONNECTICUT

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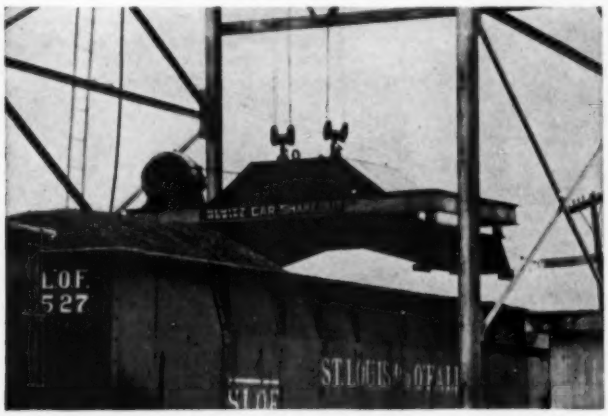
dependable, economical operation . . . speeding up production and cutting costs-per-ton.

Remember when you visit the show this year in San Francisco, make it a point to see the big exhibit of Hewitt-Robins equipment . . . talk over your bulk materials handling and processing problems with our staff of experts.

Hose. Hewitt-Robins manufactures over 1,000 types of industrial hose . . . each designed to fill a specific hose application. Hewitt-Robins hose has proved its superiority on the job. In case after case, actual performance records prove that Hewitt-Robins hose is safer, performs longer, provides greater economy.



Shakeouts. Hewitt-Robins Car Shakeouts handle wet, compacted and even partially frozen loads. Capacities vary depending upon characteristics of material. . . average unloading time under 5 minutes per car. Two types: 5-ton HD (Heavy Duty) for handling up to 100 cars per day —3½-ton GS (General Service) recommended for up to 10 cars per day. Both models available with companion twin-hook Car Shakeout Hoist.

Here is a partial list of

HEWITT-ROBINS PRODUCTS

that will help you cut handling costs and increase operating efficiency.

MACHINERY

- Belt Conveyors
- Belt & Bucket Elevators
- Car Shakeouts
- Conveyor Idlers
- Dewaterizers
- Mechanical Feeders
- Foundry Shakeouts
- Mine Conveyors
- Reclaiming Systems
- Screen Cloth
- Stackers & Trippers
- Vibrating Conveyors & Screens

INDUSTRIAL RUBBER PRODUCTS

BELTING:

- Conveyor
- Elevator
- Transmission

HOSE:

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- Barge Loading
- Dust Suction
- Fire
- Fuel Oil & Gasoline
- Gasoline Pump
- Mud Pump Suction
- Oil Suction & Discharge
- Propane-Butane
- Road Builders'
- Rotary Drilling
- Sand Blast
- Sand Suction
- Sea Loading
- Servall®, All-Service
- Steam
- Tank Car & Tank Truck
- Vacuum & Air Brake
- Water & Water Suction
- Welding, Twin-Weld®

MOLDED RUBBER PRODUCTS

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For information and service on industrial rubber products, contact your Hewitt-Robins Industrial Supply Distributor. Through his complete stock of Hewitt-Robins Rubber Products, and his familiarity with local field conditions, he can fill your supply needs promptly and correctly. See Classified Phone Book for the Hewitt-Robins Industrial Supply Distributor serving your area.

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New Products • FILL OUT THE POSTCARD FOR MORE INFORMATION • Equipment

Power Shovel

Readily convertible to dragline, clamshell, or lifting crane, the 3-cu yd *Bucyrus-Erie* model 71-B complements present line by filling gap between the 2½ and 4-yd jobs. Machine is fully air controlled, except for drum brakes and swing and propel jaw clutches. Revolving frame is one-piece welded unit. The 6-cylinder GM diesel has Torcon torque converter drive. **Circle No. 1**

Compact Load-Center

General Electric Co.'s transformer dept. recently completed a portable load-center for underground use at Los Condores tungsten mines, Argentina. Less than half as high as

conventional 150-kva load-centers, the 42-in. high package has skids to facilitate dragging and special bracing and heavy lugs for lowering unit underground. **Circle No. 2**

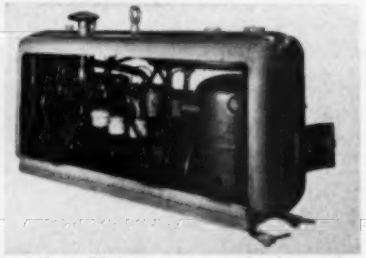
Plastic Pipe

U. S. Rubber Co. sees step forward in handling sensitive chemical solutions and acids through availability

of tough but lightweight rubber-plastic valve bodies in 3-in. diam. Working pressures to 150 psi and temperatures to 170°F are handled by new large valve of type hitherto available only up to 2-in. size. Pipe fittings in 3 and 4-in. size are also being made of Uscolite, a styrene copolymer. **Circle No. 3**

Utility Compressor

Le Roi claims its Utility 105, recently restored to the Airmaster line, is only compressor of its type on the



market. Unit uses same basic engine as the 105-cfm portable, but everything including upright air receiver is under one housing. The 82-in. overall length makes easy fit for crosswise truck mounting, and lifting bail provides for crane transfer to locations such as upper floors of building jobs. **Circle No. 4**

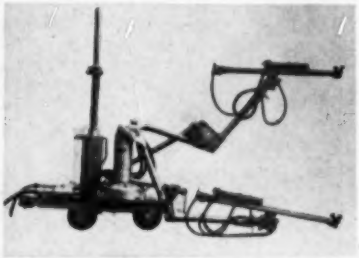
Rotary Drill Rig

Portable rigs for fast drilling of seismograph shot holes, blast holes, and for core drilling are being built

by *Drilling Accessory Mfg. Co* in sizes to handle up to 1250 or 2000 ft of 2⅜-in. drill pipe. Use of air clutch is featured. **Circle No. 5**

Drill Jumbo

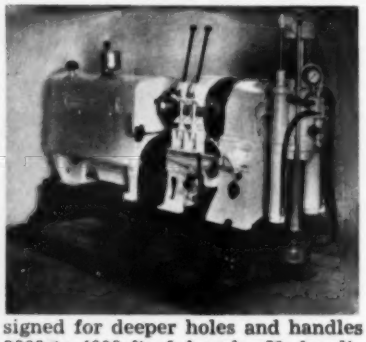
Completely air powered and controlled, new *Thor* mining jumbo mounts drifters such as the Thor



3½-in. power feed type or the 3-in. size with air bar feed. **Circle No. 6**

Diamond Drill

E. J. Longyear Co.'s new diamond core drill, to be introduced at the Mining Show is termed a "drill-runner's drill." Incorporating recommendations of operators from all over the world, the new "44" is de-



signed for deeper holes and handles 3000 to 4000 ft of A rods. Hydraulic swivel head accommodates all standard rods, including 2⅞-in. flush-coupled rods and the Longyear's Wire Line rod. Large hoist uses planetary gears and has oversize brake bands and metallic linings to handle rods safely and rapidly at depth. Diesel, air, or gasoline power is available. Controls have been centrally grouped for command of operation, and low center of gravity avoids risk of tipping. **Circle No. 7**

Track Cleaning

Push button hydraulic adjustments speed track cleaning with the Canton 30, successor to the original

model 40. *American Mine Door Co.* tailors the machine in 24 to 48-in. track gage and to various heights to suit mine conditions. **Circle No. 8**

Better Screening

Increased screening effectiveness for existing units is possible with dredge trommel that mounts inside regular revolving screen, according to *Yuba Mfg. Co.*, the builders. Dredge trommel calls for minimum change and utilizes area usually blanked by circular tread rings and blank end plates. Increase by 25 pct in effective screen area is claimed for design developed by E. Olson for a Yuba dredge at Platinum, Alaska. **Circle No. 9**

Free Literature

(21) CRAWLER TRACTORS: The complete line of *Allis-Chalmers* diesel powered crawler tractors is shown in "FACTS . . . on a New Breed of Tractors." This 16-page color brochure follows "Time" magazine's format to present an editorial message, operational methods, and specific features of the four crawlers in the A-C line.

(22) VIBRATING EQUIPMENT: *Jeffrey Mfg. Co.* has a fully illustrated 230-page catalog on Jeffrey-Traylor vibrating equipment with detailed information on feeders, conveyors, coolers, dryers, mixers, constant weight feeders, bin check valves, packers, screens, controls, and magnetic separators. Operation, application, and principles of electrical and mechanical vibration are thoroughly explained.

(23) JET SIZER: The Dorrco jet sizer, for sizing and grading of 8—mesh and finer solids, incorporates new design features that result in more effective use of hydraulic water to produce clean, deslimed fractions. *The Dorr Co.'s* bulletin No. 2342 describes mechanism, theory, applications, and advantages of this new hindered settling hydraulic classifier as well as sizes of available machines.

(24) VALVES: *Lunkenheimer* grooved end valves, available in 2½ to 8-in. sizes in standard 200-lb pressure gate valve patterns and 2-in. 225-lb pressure "King-clip" pattern are covered in new circular.

(25) MOTORPUMPS: *Ingersoll-Rand* has printed a slide film in booklet form showing what a centrifugal pump is and how it works. After considering various factors—quantity, pressure, friction losses—that must be considered in selecting a pump, a typical problem is solved.

(26) FIREPROOF BELTS: *Scandinavia Belting Co.* is offering Scandura belting that has "firmly established itself in British mines as the most economical belt yet produced as to length of life and low maintenance requirement." Now U. S. made, Scandura belts have a surface coating of plasticized PVC claimed to give the product unrivaled qualities, especially for conveyor belting.

(27) SAFETY SAVES $$$: *National Safety Council's* "Plus Cost" tells concisely how accidents nibble at

profits and outlines the "why" and "how" of accident control for small firms with few employees and no safety staff.

(28) MICROSCOPES: A new series of polarizing microscopes designed for use in the mining and minerals industry are presented in catalog D-130 from *Bausch & Lomb Optical Co.* Instruments have a ball-bearing, low-position, fine-focusing stand previously available only in B&L Dynoptic laboratory instruments.

(29) SAFE ELECTRICITY: *Crouse-Hinds Co.'s* "Electrical Equipment Design for Hazardous Locations," covers explosion pressure dynamics and explains why explosion-proof lighting fixtures, control boards, and receptacles are necessary where there are explosive gases, vapors, or combustible dusts.

(30) THERMOCOUPLE DATA: To determine the type of thermocouple and protective tube needed for virtually any operation, *West Instrument Corp.* has published "Pyrometer Accessory Catalog." Based on Instrument Society of America recommended practice, it is illustrated, indexed, and each item is priced.

(31) THICKENERS: Bulletin No. T5-B5 from *Denver Equipment Co.* is devoted to the spiral rake thickener. The patented 30° spiral rakes, available in sizes from 3 to 80-ft diam, brings the material to the center discharge cone in one revolution. This minimizes the chance of choke-ups in the tank, thus assuring continuous operation.

(32) DIESELS: "The Dependable Diesel" is an external house organ published by *Cummins Engine Co.* Short articles illustrated with drawings and photographs show Cummins diesels at work from Brazil to Canada, Maine to California.

(33) RUST REMOVER: A nonacid rust remover that simultaneously strips paint, rust, and primer from ferrous metal surfaces is described in brochure from *Turco Products Inc.* Called Rustgon, the liquid alkaline material requires only two simple steps—dip and pressure rinse.

(34) MACHINING STEEL: *Joseph T. Ryerson & Son* bulletin describes Ledloy—lead bearing steel—said to be fastest cutting steel ever made. Case studies show production increases "up to 72 pct."

(35) ZIRCONIUM: "Facts About Zirconium," published by *Carborundum Metals Co.*, is 64 pages of concise information about the history and production of zirconium. Mechanical, physical, and chemical properties as well as fabrication data are covered.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after December 15, 1954 — if mailed in U. S. or Canada

Please send me { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
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61	Students are requested to write direct to the manufacturer.								

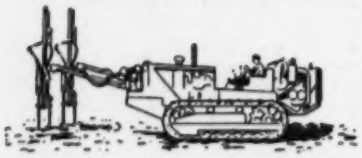
Name_____ Title_____

Company_____

Street_____

City and Zone_____ State_____

(36) COMPRESSOR TRACTOR: *Le Roi Co.'s* bulletin on the 600 CTM tractor-mounted compressor points out that the recently introduced power take-off compressor is available for mounting now on any lead-



ing make of crawler tractor. The first manufacturer to introduce such a unit with a clutch and direct drive, the company is also the first to offer a compressor of this type completely assembled.

(37) TRUCKS: *Fuller Mfg. Co.'s* latest issue of "Transmission Topics" tells how trucks are used in the aggregates industry and how trucks and specialized powered equipment serve the petroleum industry. Also shown is the application of torque converter couplings in the materials handling field.

(38) HIGH TENACITY RAYON: *Du Pont* booklet presents up-to-the-minute facts about a high tenacity rayon in the mining and quarrying industries. "Cordura," a rugged durable fibre, with a tensile strength equivalent to 70,000 psi, is being used for conveyor belts, hose, V-belts, and heavy duty off-the-road tires.

(39) QUARRY OPERATIONS: *Caterpillar's* "Producing on Schedule in Pit and Quarry" has photographs of equipment operating in quarries across the country. The 8-page booklet also includes complete chart of diesel engines and generator sets, with their hp and kw ratings.

(40) GAS ANALYSIS: Electro-conductivity gas analyzers by Davis with instrumentation by Honeywell are described in data sheet 10.15-12 from *Minneapolis-Honeywell Regulator Co.*

(41) PLASTIC VALVES: *Industrial Plastic Fabricators'* bulletin covers valves of unplasticized polyvinyl chloride in needle and globe types. Information is also given on Fluoroseal pipe compound, suitable for metal and plastic piping, which provides a positive seal, but retains its viscosity.

(42) MOTOR STARTERS: Booklet 1062 from *Electric Controller & Mfg. Co.* describes motor starters having short circuit protection for 2200 to 5000-v systems. Illustrated are starters of 50,000 kva interrupting capacity, and Valimitor starters, which will safely interrupt the circuit from a supply bus of unlimited capacity—the kva may be infinite—while limiting pass-through current to 25,000 kva.

(43) FLOTATION REAGENTS: Cachalot is the registered trade name for straight chain monohydric alcohols vacuum-distilled from the oils of the sperm whale. *M. Michel & Co.* booklet tells how Cachalot brand cetyl, oleyl, and stearyl alcohols serve as emulsifiers, flotation reagents, foam inhibitors, etc.

(44) BLOWERS: *Chicago Blower Corp.'s* bulletin CTB-103 contains charts and specifications on high-pressure turbo blowers for use with oil and gas burners on industrial furnaces.

(45) FIELD RATIONS: *Multiple Breaker Co.* folder explains "custom-built" rations. Company will prepare rations to meet: increased or reduced caloric values; permissible weight; widely varying climatic conditions; storage or carrying requirements; local or regional diet variations.

(46) CHEMICAL FEEDER: Small, low cost feeder for metering, mixing, and dispensing small quantities of liquid chemicals is illustrated with specifications and installation data in *Fischer & Porter* catalog sheet 70-50.

(47) PLUG VALVE ACTUATORS: *Ledeem Mfg. Co.'s* plug valve actuators are pneumatically and hydraulically operated for power operation, remote control, labor saving and safety installations, and automatic processing. Bulletin shows actuator selection table, typical applications, dimensions, weights, and various mountings.

(48) TIN: Out of print for several years, a completely revised edition of "The Properties of Tin" has been issued by the *Tin Research Institute.* Main divisions are: atomic and nuclear properties, line spectra, X-ray data, crystallography; optical, electrical, magnetic, thermal, and mechanical properties.

(49) FLUORESCENT LIGHTS: "Fluorescent Guide" from *Sylvania Electric Products Inc.* tells in non-technical language what fluorescent lighting is, its advantages; and gives lamp sizes, colors, and accessories.

(50) TRACTOR-SHOVELS: *Frank G. Hough Co.'s* form No. 272 shows applications of Payloader tractor-shovels at pits, plants, smelters, and

refineries. Useful attachments illustrated include backfilling-blades, crane-hooks, fork-lifts, and backhoes.

(51) SAND PUMPS: For information on *Wilfley* 8-in. model K sand pumps described on inside front cover.

(52) LOST COST FLOTATION AGENTS: For 16-page booklet from *Hercules Powder Co.* See page 870.

(53) PREFABRICATED DOCK: For illustrated booklet describing advantages offered by *De Long Corp.* dock. See page 852.

(54) NEAR-SURFACE SEISMIC DATA: For *Houston Technical Laboratories* technical bulletin No. S-303. See inside back cover.

(55) FORGED STEEL DROP BALL: For information from *Cape Ann Anchor & Forge Co.* See page 937.

(56) PACKAGED MINE HOISTS: *Aros Electric Inc.'s* bulletin on multi-rope hoists. See page 861.

(57) CALCINE COOLER: For bulletin from *Stearns-Roger.* See page 859.

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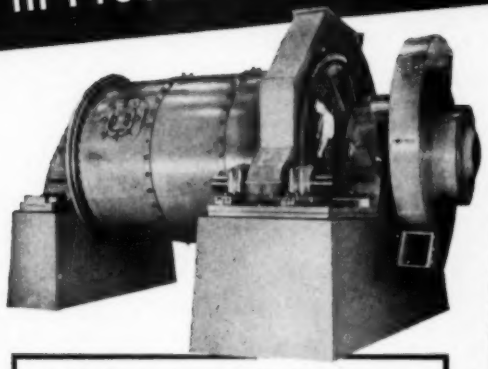
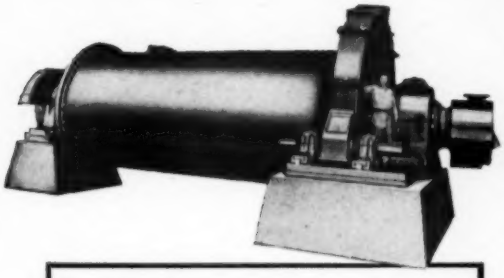
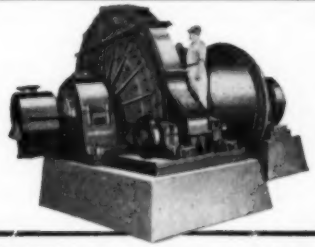


NORDBERG 10'-8" x 17' Wet Grinding Ball Mill showing scoop feeder.



NORDBERG 9'-6" x 24' Wet Grinding Pebble Mill for non-ferrous milling.



NORDBERG 9'-6" diameter x 11' long Dry Grinding Mill.

MORE than half a century of progressive engineering achievement, combined with quality production in modern manufacturing facilities, have won for Nordberg a foremost position in the field of heavy machinery manufacture.

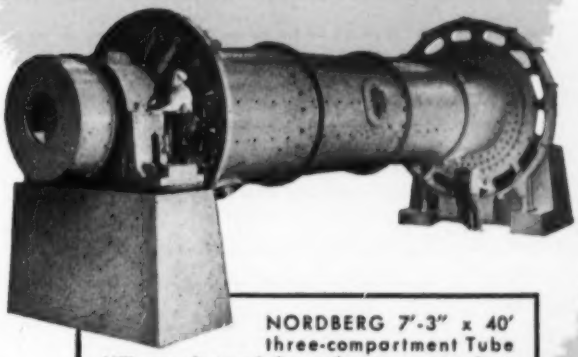
Typical of this heavy machinery is the complete line of Nordberg Grinding Mills available for the manufacture of Cement, the extraction of Metals from Ores, and in the processing of Non-Metallic Minerals, which require comminution to fine sizes.

Nordberg manufactures Ball, Tube, Rod and Compartment Mills, of grate, overflow and peripheral discharge types for wet or dry grinding service, in sizes ranging to 13'-0" diameter, and in lengths to 40'-0".

Competent engineering services are available for new processing plant design or modernization of existing plants.

For large or small operations, you can depend on Nordberg Machinery to deliver maximum output at lowest possible cost.

NORDBERG MFG. CO., Milwaukee, Wisconsin



NORDBERG 7'-3" x 40' three-compartment Tube Mill manufactured for a large cement plant.

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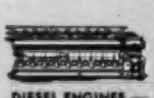
SYMONS VIBRATING GRIZZLIES

SYMONS VIBRATING SCREENS



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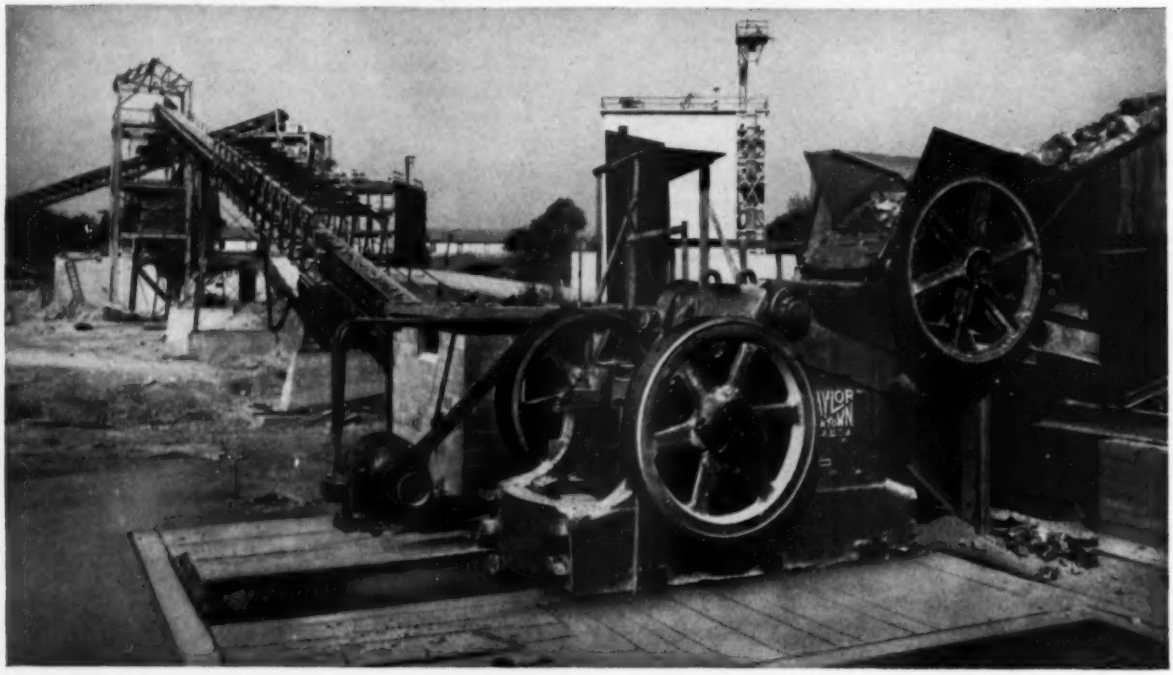

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I'd like to know more about the Traylor Type "R" Crusher and its pay-off in increased production.

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I am crushing _____ *tons per hour with a* _____ *crusher.*

a **Traylor** *leads to greater profits*

Today, the initial cost of a machine is not the deciding factor in its installation. Production potential is the prime consideration. A Type "R" Jaw Crusher is "Traylor-Made" to make money for its operator. With feed openings from 36" x 48" to 48" x 60", a Type "R" Traylor Crusher can produce 130 to 550 tons per hour of 2" to 9" product. The main reason for the Type "R's" amazingly high rate of production is its original Traylor Curved Jaw Plates. The several ways in which Traylor curved jaw plates lower production costs are clearly described in Bulletin 1123. Mail coupon for your copy today.

Primary Gyratory Crushers | Rotary Kilns | Secondary Gyratory Crushers | Ball Mills | Jaw Crushers | Apron Feeders

CHIBULUMA MINES LTD. announced plans to build a cobalt treatment plant at Ndola, Northern Rhodesia. The site is adjacent to one on which Ndola Copper Refineries Ltd. plans to construct an electrolytic copper refinery. Chibuluma, a subsidiary of Rhodesian Selection Trust, will own the cobalt facility. The first stage of a three-stage program is expected to mature in 1956, with electric smelting to produce a matte containing cobalt and copper. Cobalt oxide will be produced in the second stage, and cobalt metal in the third. Total cost of the plant will be approximately £500,000.

Gaspe Copper mine development is expected to have mine and mill in operation shortly after hydroelectric power becomes available in October. Smelter operation is scheduled for early 1955.

AMERICAN METAL CO. LTD., New York, and Canam Copper Co., Vancouver, B. C., have signed an agreement to develop Canam's copper property 28 miles from Hope, B. C. Under the arrangement a new company will be formed, with American Metal eventually owning 60 pct and Canam 40 pct. American Metal will spend up to $300,000 in development and exploration. The New York firm is also expected to spend as much as $5 million for production facilities.

Fenimore Iron Mines Ltd. has retained Battelle Memorial Institute, Columbus, Ohio, to estimate cost of an iron ore concentrating plant at Ungava Bay, on Canada's North Atlantic coast, for a 1 million ton annual capacity. Part of Battelle's job will be to determine concentration characteristics of Fenimore's North Finger Lake ore deposit. The district contains about 200 million tons ore mineable by open pit and close to tidewater. Fenimore's two concessions in Ungava contain some 1 billion tons of ore.

ACCORDING TO THE AEC there are now 430 operators producing uranium ore from 530 mines in the U. S. Most of the mines are on the Colorado Plateau. It was also revealed that there are 15 known deposits of more than 100,000 ton reserves each.

EUGENE G. GRACE, chairman of Bethlehem Steel Corp., recently read a statement made by J. L. Mauthe, president of Youngstown Sheet & Tube Co. which said: "There have been discussions between the officials of Youngstown Sheet & Tube Co. and Bethlehem Steel Corp. with respect to a consolidation. No agreement has been reached, as there are a great many details yet to be discussed."

LITHIUM CORP. OF AMERICA INC. announced an agreement with Quebec Lithium Corp., subsidiary of Sullivan Consolidated Mines Ltd., for development of an orebody 25 miles from Val d'Or, Que. The Canadian firm plans to build a concentrating plant. Under the pact Lithium will process the entire output of the mill at its St. Louis Park, Minn., and Bessemer City, N. C., plants. The contract, according to the American corporation, will allow Lithium to double output.

Bolivian President Victor Paz Estenssoro claims that nominal output of tin during 1953 was maintained despite falling prices. Bolivian mines turned out some 35,384 tons. He further stated that financial troubles have been overcome by Banco Central credits. Foreign experts are now working on a project for erection of a tin smelter in Bolivia. Companies whose mines were nationalized were being credited with a percentage of export revenues. Amounts to July 31 were: Patino, $971,174; Hochschild, $309,656; and Aramayo, $448,406.

AVERAGE STARTING SALARIES for June 1954 engineering graduates indicate that the 10-year spiral has started to level off, according to the Illinois Institute of Technology. The 1954 crop of engineers are averaging $363 per month, about $1 more than last year.

In a move to prevent strategic materials going to the USSR or her satellites, the Belgian Congo has issued a decree requiring preliminary authorization for the export of ores, metals, special alloys, and byproducts of beryllium, bismuth, cobalt, columbium, lithium, magnesium, molybdenum, sodium, strontium, tungsten, tantalum, titanium, thorium, vanadium, zirconium, and rare earths. The decree also requires authorization for export of aluminum, tin, and lead in form of metal, ore, or semifinished products.

Seasoned observers are predicting an early closing of the Great Lakes ore shipping season compared with other years. By the end of July six vessels had been taken out of service and more recently Pittsburgh Steamship Div. of U. S. Steel Corp. announced it would lay up 15 of its 59 ships September 1. Bethlehem pulled two freighters out of service. A July survey showed that fewer than 200 of the 275 ore carriers available were in action during that month.

BREAKING THROUGH TO NEW HIGHS WITH THE NEW U. S. SUPER USTEX-

for higher and higher lifts

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The high-strength belt for high-tension work

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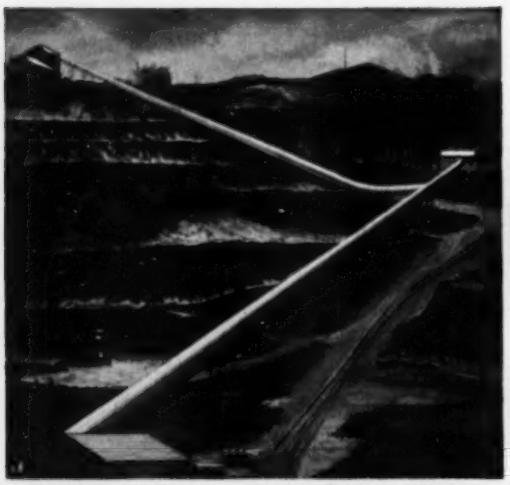

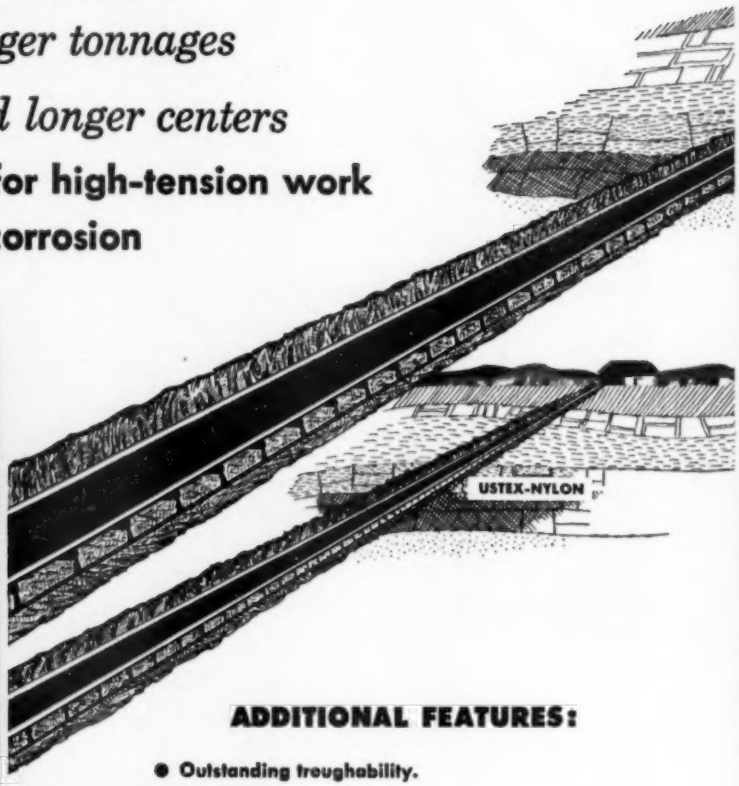

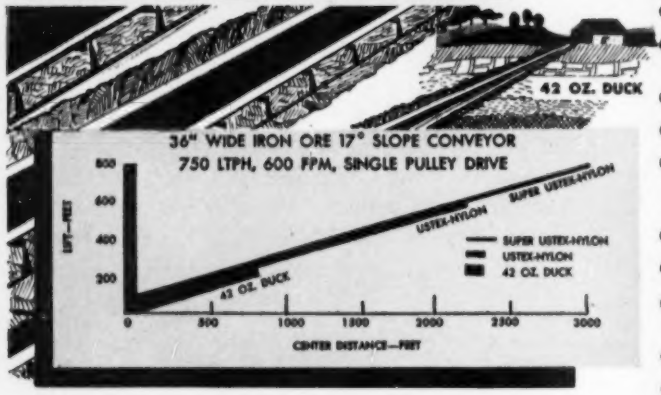

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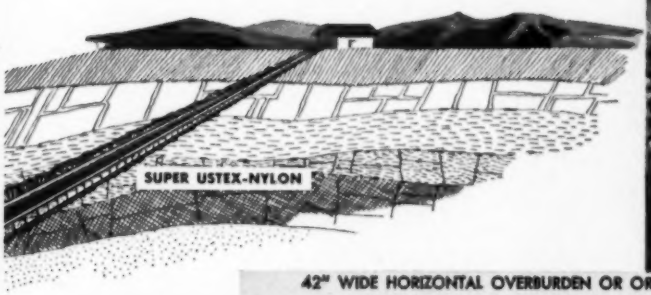

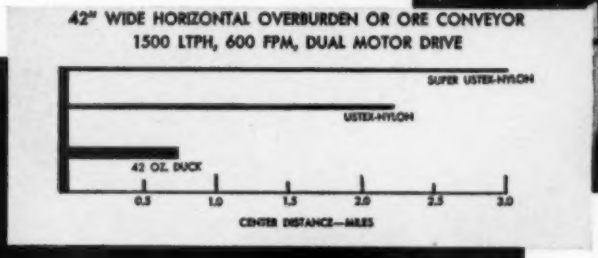

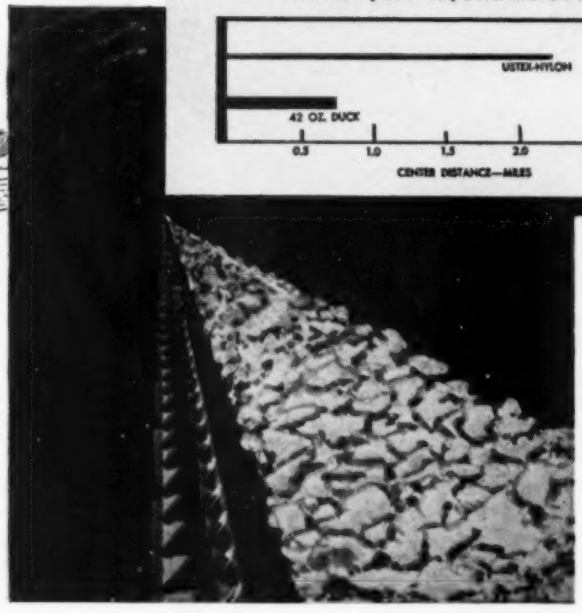

This great new Super Ustex-Nylon Belt is the latest in United States Rubber Company's parade of Belt Champions.

In 1929, "U. S." gave mine haulage a history-making lift—by presenting the 42-oz. duck belt, later to become standard in the industry.

In 1939, "U. S." came out with the strongest belt ever made up to that time—the famous 48-oz. duck belt. So strong was this belt that the first one installed is still in active service.

In 1948, still anticipating that in the years ahead mine operators would find it necessary to haul ever-increasing tonnage up higher and higher lifts, "U. S." introduced the Ustex-Nylon Belt—to handle the great tensions that were undreamed-of years before. The first of these belts was installed in a Minnesota iron mine where it carried over 7,500,000 long tons of ore at a rate of 700 long tons per hour for several years. It was then moved to a new location and now handles 1,200 long tons per hour up a higher lift. In other words, the belt is doing twice the work it was originally designed for.

And now, in 1954, again the Iron Range takes advantage of our Three-way Engineering. A leading original equipment manufacturer specifies our latest champion, the Super Ustex-Nylon Belt for one of the foremost iron ore producers.

There is always a "U. S." sales engineer ready to work out haulage problems for you through Three-Way Engineering—the "U. S." method of working with mine engineers and the designers of conveyor equipment. Consult any of the 27 "U. S." District Sales Offices, or write to address below.

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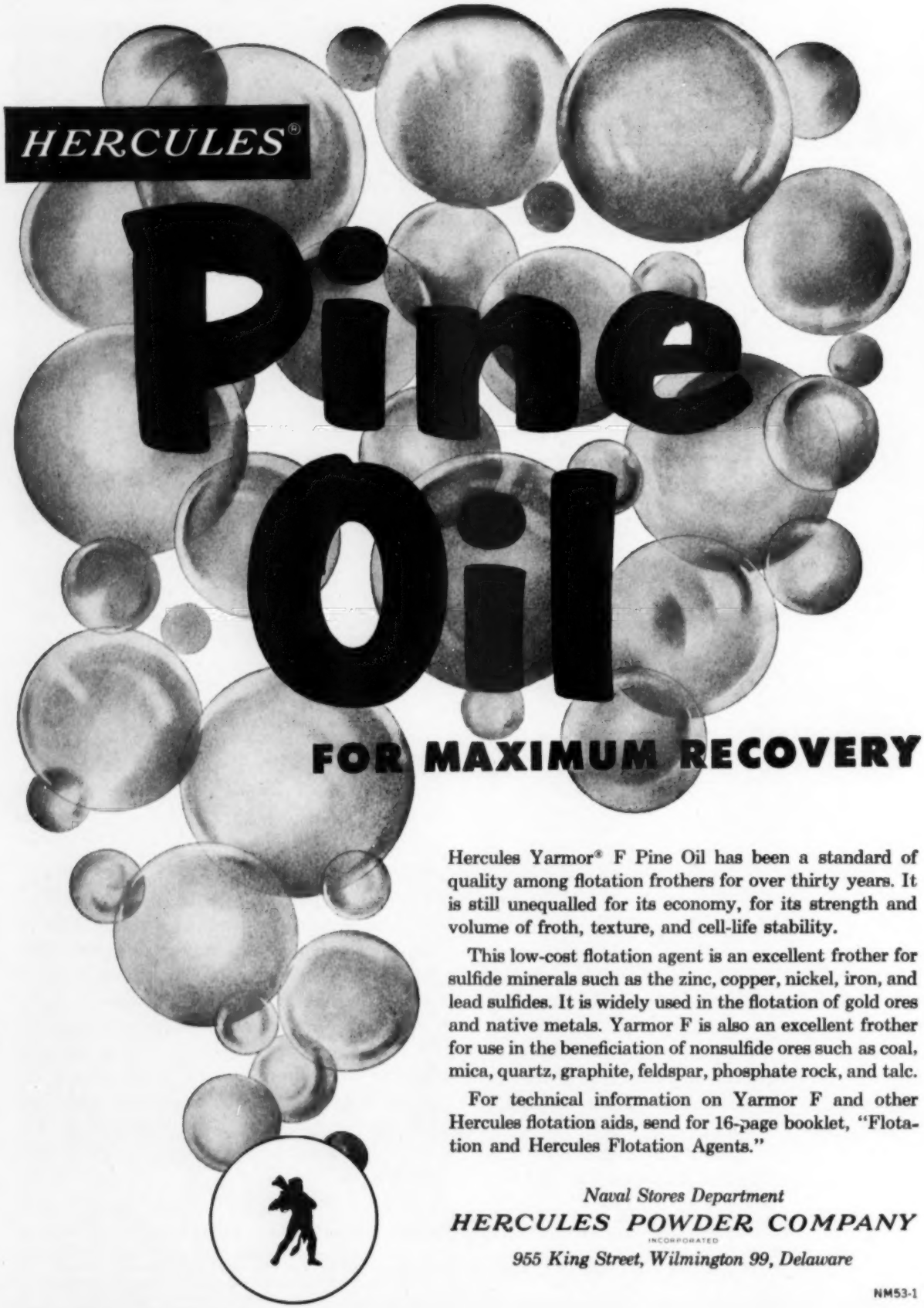


Hercules Yarmor® F Pine Oil has been a standard of quality among flotation frothers for over thirty years. It is still unequalled for its economy, for its strength and volume of froth, texture, and cell-life stability.

This low-cost flotation agent is an excellent frother for sulfide minerals such as the zinc, copper, nickel, iron, and lead sulfides. It is widely used in the flotation of gold ores and native metals. Yarmor F is also an excellent frother for use in the beneficiation of nonsulfide ores such as coal, mica, quartz, graphite, feldspar, phosphate rock, and talc.

For technical information on Yarmor F and other Hercules flotation aids, send for 16-page booklet, "Flotation and Hercules Flotation Agents."

Naval Stores Department
HERCULES POWDER COMPANY
INCORPORATED
955 King Street, Wilmington 99, Delaware

NM53-1

At Kaiser Steel Corp.'s Eagle Mountain, Calif., iron ore mine, the ore goes from the primary crusher, lower left, to the building, upper left, where magnetic and Heavy-Media separation units further up-grade existing high quality iron ore. The plant was constructed by Kaiser Engineers Div. of Henry J. Kaiser Co.

Kaiser Eagle Mountain Separation Plant Operating

Kaiser Steel Co.'s new magnetic and Heavy-Media separation plant at Eagle Mountain, Calif., is designed to handle 2 million tons of ore annually.

Average content of ore from the Eagle Mountain mine is 51 pct iron before upgrading. After processing iron content is reported to be 56 pct. Higher grade product will yield transportation economies and improved blast furnace efficiencies at Fontana steel works.

Eagle Mountain has undergone a steady expansion. In addition to a new recreation hall and 96 homes, Kaiser has erected a television transmission tower enabling the 200 employees and their families to view Los Angeles broadcasts.

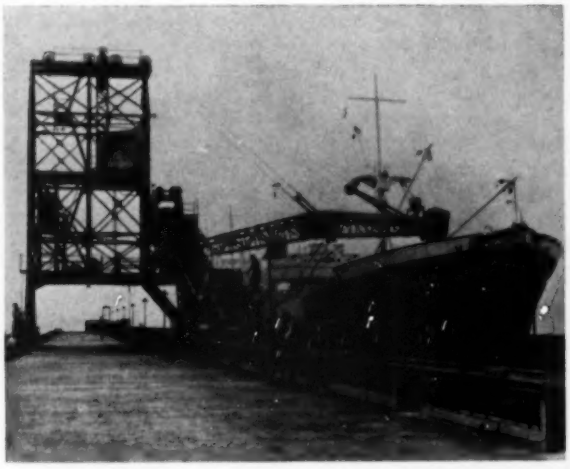
Daniel C. Jackling Statue Unveiled

Art, industry, and the clergy lauded the contributions of Daniel C. Jackling at ceremonies hailing the 50th anniversary of Utah Copper Div., Kennecott Copper Co. in Salt Lake City.

Highlight of the program on August 14, Mr. Jackling's 85th birthday, was unveiling of a 9-ft bronze statue of the "father of the porphyries."

Among the speakers were: Charles R. Cox, president of Kennecott Copper Corp.; Nicholas G. Morgan, Sr., president, the National Society of the Sons of Utah Pioneers; J. Bracken Lee, Governor of Utah; J. Rueben Clark, II, second councilor of the first presidency, the Church of Jesus Christ of Latter-Day Saints; and Avard Fairbanks, sculptor of the statue. (*See* MINING ENGINEERING, *August, p. 841*).

Day before the Jackling statue was unveiled, the new Kennecott Research Center on the campus of the University of Utah was dedicated. Among the speakers were J. P. Caulfield, general manager of Kennecott Copper Corp.'s Western Mining Divisions; Gus P. Backman, secretary of the Salt Lake City Chamber of Commerce; Most Rev. Duane G. Hunt, Bishop of Salt Lake City, Roman Catholic Church; Governor Lee; Mr. Cox; and A. Ray Olpin, president of the University of Utah. The new center was accepted on the behalf of the corporation by its director, S. R. Zimmerley.



This B. F. Goodrich conveyor belt carries 2000 tph of iron ore along the new 1100-ft steel and cement dock at San Juan Bay, Peru. Ore is being loaded from Utah Construction Co.'s Marcona mine. The belt travels 300 ft per min, making it possible to fully load ships in less than 8 hr.

The Johns-Manville Munro mine at Matheson, Ont., is undergoing some changes. The open pit asbestos mine in the foreground is gradually being changed to an underground operation. Administration and maintenance buildings, mill, and rock crusher buildings are in cluster in front of tailing pile.

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Eimco 105's with excavator attachments dig in forward motion and discharge overhead to the rear. Standard models will load ordinary trucks, high discharge models will easily load high railroad gondolas.

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B48

First Aluminum Flows from Kitimat-Kemano Project

Two mighty industrial projects, in themselves symbolic of the surge of Canadian economic development, reached maturity this summer. Iron ore from the gray-green hills of Labrador-Quebec became a reality after years of exploration, planning, and building when Iron Ore Co. of Canada started shipping to eastern U. S. ports from Sept Iles. Almost at the same time, on Canada's west coast, Kitimat, the aluminum smelter in the British Columbia wilderness, poured its first aluminum ingot. *(For the story on Iron Ore Co. of Canada see p. 884.)*

Kitimat is an area that until a short time ago was inhabited by only a few Indians. Today, it represents what may someday develop into a vast industrial center. Eventually, Kemano, the hydroelectric power project that made the smelter possible, will have a capacity of 2.24 million hp—largest ever undertaken by private enterprise. It will supply a smelter with an annual capacity of 550,000 tons of primary aluminum. Initial hydroelectric capacity will be 420,000 hp, producing some 91,500 tons annually. Thus far, three years and $275 million have been expended in the development of Kitimat-Kemano since the project was first announced Apr. 21, 1951 by Aluminium Ltd., parent company of Aluminum Co. of Canada.

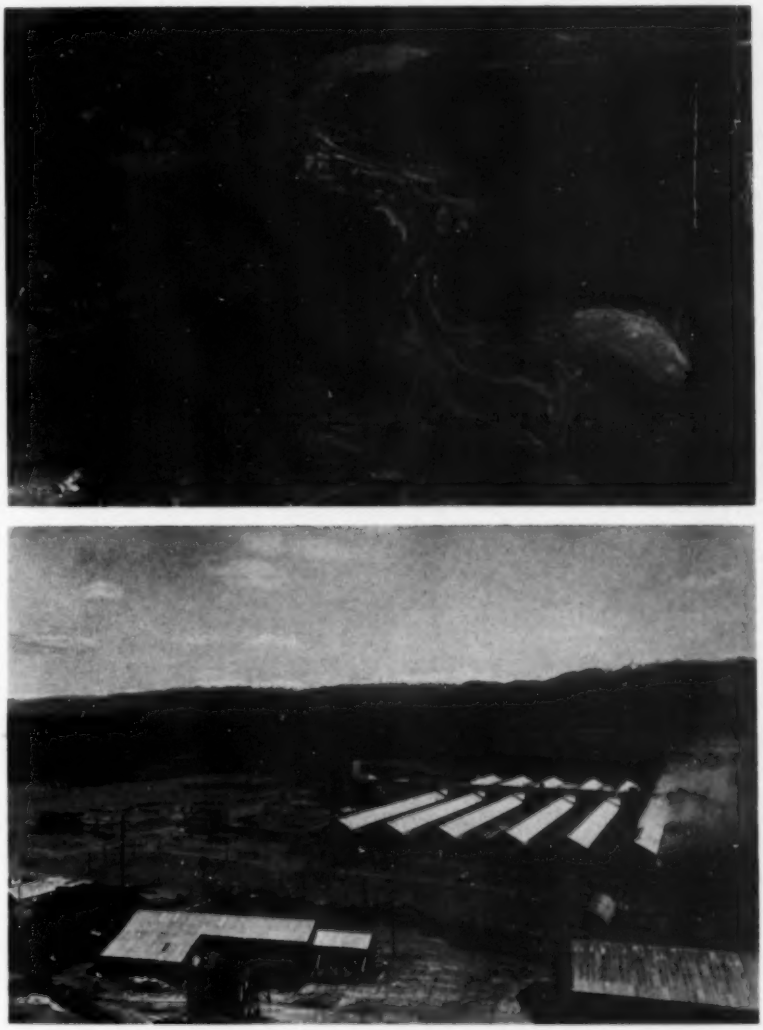
The Kemano powerhouse containing the three 140,000 hp turbines is a gigantic cavern dug a quarter of a mile into Mount DuBose. Water drops 2600 ft through penstocks to drive the turbines. One of the more spectacular construction feats was the driving of the 10-mile tunnel carrying water from the Kenney Dam on Nechako River.

The smelter is set in a broad river valley 400 miles north of Vancouver and 100 miles from Alaska. One advantage of the smelter is its proximity to tidewater. Tight construction schedules allowed no time for fill settlement. Thus, the one group of tall buildings were constructed at a slight angle. As the fill settles the buildings will become perpendicular. The first section of the smelter is one half mile long. Another two miles will be added when plans for the future are carried out. Pot lines and subsidiary buildings now are about 1230 ft long with a width of 1000 ft. Ventilation fans are on the roof. Exhausts from pots meet at one main duct which carries fumes through gas scrubbers servicing two buildings at a time.

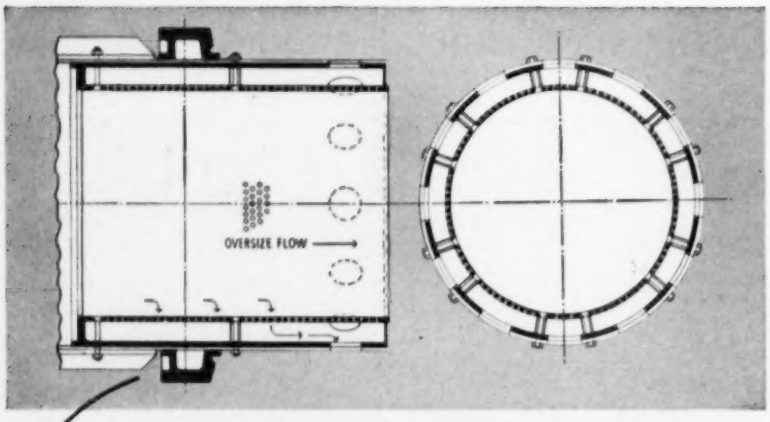
Kitimat is a showcase for the growth of aluminum in the electrical and construction industries. Some 15 million lb of the metal were used in the first stage of smelter and hydroelectric development. Aluminum was used in the 275 kv switching structure, and the smelter itself consists of a steel framework with aluminum roof and sidings. Aluminum bus bars are used exclusively at both Kitimat and Kemano. At various points in the installation flat bus, channel bus, tubular bus, and flexible bus bars are employed. Huge amounts of bare aluminum cable are used in electrical equipment.

Helicopters helped lick one of the toughest problems in the Kitimat-Kemano undertaking. Towers that carry the 50 miles of transmission lines from Kemano to Kitimat were constructed, tested, and then broken into sections. The whirly birds carried the sections to points along the route where crews reassembled them.

Bauxite for the Kitimat smelter comes from the company's Jamaica properties, where it is reduced to alumina before shipment. Bulk alumina is brought through the Panama Canal and up the West Coast of North America to British Columbia. The British Columbia coast can be a mariner's nightmare, with mountains that plunge into the sea, thick dangerous fog, and an extremely high tide. The smelter is 100 miles inland on a fjord-like channel which ends with the delta at the mouth of the Kitimat River. The port is ice free the year round.



THE START AND THE FINISH. Power for the Kitimat project is born at the Kenney Dam (top). It holds back the 125-mile chain of lakes forming the reservoir for the power plant at Kemano. The dam is 320 ft high, 1500 ft long, and 1300 ft wide at the base. A 10-mile tunnel, a power house built into a mountain, and 50 miles of wire stretched over treacherous country, lead energy to the Kitimat smelter (bottom), where an initial annual production of 91,000 tons of aluminum is expected.



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Now, increase screening capacity as much as 25% without lengthening your screens, with the new Olson patented dredge trommel.

Here's how: Olson dredge trommel mounts inside present revolving screens in the area usually blanked out by circular tread rings and blank end plates. Its perforated holes convert this blank space into an inner screening area that: (a) greatly increases screening capacity or (b) provides better classification of screened material through smaller perforation sizes.

Coarse material goes out the end, as in any conventional revolving screen; but fines pass through the perforated holes of the Olson trommel onto the blank shell plate; then through large holes to join fines from the forward screening area.

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Eagle-Picher Buys Calumet Property

Eagle-Picher Co. bought the lead-zinc mine near Shullsburg, Wis., from Calumet & Hecla Inc. Purchase price was not disclosed.

Calumet & Hecla geologists discovered the Shullsburg orebody in 1947 and the mine has been operated commercially since 1951. Output was reported at about 1200 tons of concentrates per month.

Endicott R. Lovell, president of Calumet & Hecla, said that the sale was in line with a long-range program designed to convert some of the company's assets into working capital for more profitable use in other areas. T. Spencer Shore, Eagle-Picher president, said the purchase included leaseholds on about 3650 acres, as well as a mill, supplies, and materials.

The Eagle-Picher executive noted that the acquisition will more than double his firm's ore reserves in the Illinois-Wisconsin area. Mining properties and equipment of Bilharz Mining Co. and the Gordon mine of the American Smelting & Refining Co. were purchased last year.

Frobisher Is Given B.C. Water Rights

Frobisher Ltd. has been given the go-ahead on its plan to develop water power in British Columbia by the provincial legislature. Aluminum Co. of America and Frobisher have been bidding for the rights.

Alcoa planned to export the power for a proposed Alaskan aluminum smelter. Probably the major reason Alcoa lost the fight was the ban by the Canadian Government on the export of water power.

Frobisher, operating through Northwest Power Industries Ltd., posted a $2.5 million bond to assure expenditure of $270 million by 1962. The Canadian group plans to apply the cheap hydroelectric power from the Yukon basin to smelt ore from property owned by Frobisher-Ventures.

A goal of 880,000 hp has been set for 1962 with a more immediate objective of 120,000 hp by 1957. Construction is scheduled to start Oct. 1, 1955. A permanent community of 20,000 is expected to grow in the Atlin area as a result of the project.

Reynolds Metals Co. and Frobisher have been discussing possible Reynolds participation in the project. However, no agreements have been reached.

Power Conference

Vienna is scheduled to be the scene of the World Power Conference June 18 to 23, 1956, with a study tour following the formal part of the program.

This is the floor of Michigan Limestone's new dolomite quarry in the Upper Peninsula. Blasting holes are being drilled in preparation for the crusher foundation.

Terrain for the railroad right-of-way is rugged—even beavers give construction men a hard time. At one point the amphibious rodents rebuilt a dam at night.

Michigan Limestone's Cedarville Quarry on Way to Production

Limestone is one rock that mother nature managed to supply in abundance, but the old lady occasionally exhibited a bad head for figures—the kind that tell the tale of economic plausibility. Michigan Limestone Div., U. S. Steel Corp., is preparing production facilities at its new quarry 5 miles from Cedarville, Mich., and the economic factors involved appear more than favorable.

The limestone deposit is part of the Engadine formation in the Niagaran series of the Silurian system. Chemical content is about 45 pct magnesium carbonate and 55 pct calcium carbonate, with only 0.5 pct impurities. It is exceptionally low in silica, phosphorus, and sulphur content. Thus, it has a magnesia content in excess of 21 pct. The occurrence lies near the surface with little overburden to worry about.

In addition to qualities that make it applicable to metallurgical use, the Cedarville limestone is desirable for concrete aggregate, agricultural lime, and many other uses.

Construction crews have been at work since April 1953, bringing in most of the equipment and supplies on trucks. Five miles of railroad line are being pushed through raw terrain and swamp. A primary crusher is under construction on the quarry floor, 46 ft below the surface.

Supervising the operation are Michigan Limestone's chief engineer, Thomas C. Jackson, and C. R. Dolsen, operating manager of the quarry and the port plant. More than 3 million tons of dolomite limestone are expected to be shipped annually. The port will be in operation by next spring, while dolomite quarries and processing plants will be working by late fall. The port is located between Bush Bay and McKay on Lake Huron 34 miles south of Sault Ste. Marie. Operation of the quarry and facilities at Cedarville is under the administration of the Division's northern district with headquarters at Rogers City, Mich.

The 620-ft dock of U. S. Steel Corp.'s Port Dolomite development nestles in the natural harbor of McKay Bay on Michigan's Upper Peninsula. The port will operate by next spring.

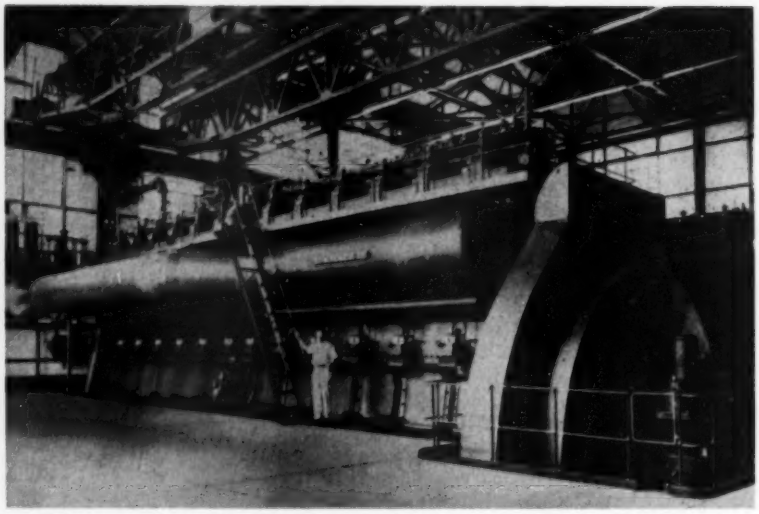
The seven-story high screening house processes dolomite into eight grade sizes which move into the storage galleries. Some of the galleries can be seen protruding from the plant.

Anglo-Lautaro Diesel Plant Boasts Unique Features

Coya Sur Designed To Meet Future Needs

When a plant assimilates big engines coupled with remote controls, high recovery of waste heat, and many new labor saving operating ideas, it's worth looking at. That about sums up Anglo-Lautaro Nitrate Corp.'s diesel installation at Coya Sur, Chile. While it may not be the biggest diesel installation in the world, it incorporates a great many features lacking in other plants.

The recently completed two-engine plant at Coya Sur forms part of a three plant network all within a radius of 10 miles, whose combined power generating facilities add up to 46,000 kw. Anglo-Lautaro Nitrate's operations cover a large area in the nitrate fields inland from Tocopilla and Antofagasta. Two equally large nitrate plants are located at María Elena and Pedro de Valdivia. In addition, the company owns a partially electrified 45-mile railroad between the plants and the port works at Tocopilla.



This is one of the two Nordberg two-cycle, 29-in. bore, 12-cylinder diesel engines at the Coya Sur power plant. They are rated at 8950 bhp, 171 rpm at the 4166-ft elevation of the plant. Engines drive 7000-kw General Electric generators.

Expansion Demands

Behind the construction of the new generating facility was an expansion that had brought about a situation where plants were operating without reserve power. Because of this, it was impossible to expand or further electrify the ore haulage system. More expansion meant providing more power.

Coya Sur is now and probably will continue for the life of the properties as the center of the load for the entire electrical system. The solar evaporation plant may be enlarged within the near future and a nearby power source would be convenient. In addition, waste heat from the power plant can be utilized in the form of hot water or steam. Waste heat is of immediate use to heat solutions in existing evaporating ponds, increasing evaporation rate.

Mexican Facility

Anglo-Lautaro engineers had in mind the type of engines installed by Nordberg Mfg. Co. for the Mexican Power & Light Co. at Tacubaya, Mexico. The Mexican Light & Power units were rated at 8650 bhp at sea level and 167 rpm for driving 50 cycle generators. After the units were first installed in 1949, Nordberg redesigned the combustion space, resulting in fuel rate improvement. This type of engine, installed at Coya Sur, is rated at 9600 bhp at sea level, or 8950 bhp at the 4166-ft elevation of Coya Sur, when operating at 171 rpm. Margin of 10 pct overload for 2 hr in any 24 hr period has been retained.

The engines are vertical, two-cycle, crosshead type with mechanical injection. They are 12 cylinder, in-line jobs of 29-in. diam and 40-in. stroke. Brake horsepower of 8950 and electrical rating of 6400 kw at 80 pct power factor are net capacities after deducting power required to drive the scavenging blower. Power input to the motor driving the blower is about 545 kw when the engine is operating at full load.

Engine Room Spacious

Generators furnished by General Electric Co. are the flywheel type, totally enclosed for forced air ventilation, and rated at 8750 kva, 7000 kw at 80 pct power factor.

The company's engineering office designed and detailed the steel structures to house the engines and their auxiliaries. With the idea of size acting as an inspiration to good housekeeping and to provide room for safe handling of large pieces around the engines, the main engine room is 84x108 ft. A gallery along the east wall at engine operating platform level provides space for walk-way between machines and the fuel oil heating and filtering units.

Engine bedplates were flushed with the floor by pouring concrete foundations a few feet below engine room floor level. Bedplates, in two halves, are not bolted to the foundation, but rather rest on shims which in turn rest on machined surfaces of special box type cast iron girders. These girders are concreted into the foundations for the length of the engines. There are eight cast-in chocks on each side of the engines, wedging the bedplates against horizontal movements. Seismic disturbances made this special arrangement necessary.

A full width glass partition separates the control room lean-to from the main engine room. The operator sits in air conditioned comfort watching warning lights and auxiliary equipment push-button switches. In addition to the standard control room equipment, special gage boards and control panels have been installed for each engine.

Air Washers

An exhaust pyrometer indicates the temperature for each cylinder, with a transfer switch mounted on the control panel along with an engine alarm system. Should excessive temperature be reached, howlers and lamps give warning. All of the electrical switch gear and controls are General Electric products, with exception of special control panels furnished by Nordberg.

Two air washers are required for each blower fan, and are mounted one above the other on different floors. Air washers are of the centrifugal spray variety with louvered intake on the outside of the building. Eliminators are on the fan side. American Blower Corp. furnished the four air washers.

A 5000-ton capacity all welded tank stores incoming fuel oil. Fuel is drawn as required through a steam heater adjacent to the tank, by pumps. Heated oil is then pumped through a Cuno Auto-Klean edge type filter and into another steam heater which is thermostatically controlled to maintain constant centrifuging temperature.

Combustion Engineering built waste heat boilers, operating at 25 psig, each evaporate about 6500 lb per hr of river water. Under normal engine operating conditions exhaust gas enters the waste heat boilers at 450° and leaves at about 350°F. Generated steam is principally used as distilled make-up water for the engines and air washer system.

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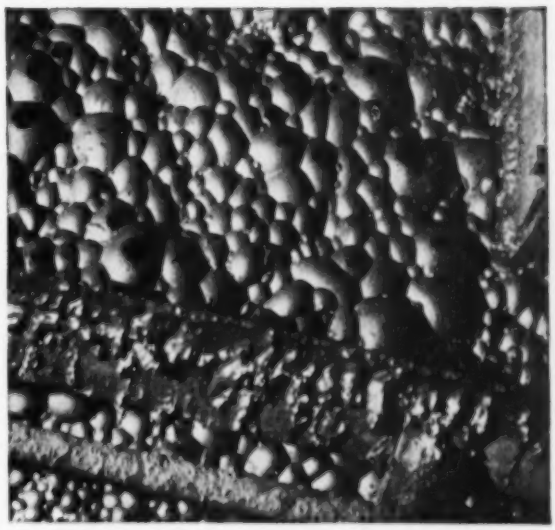

DOW XANTHATES bring mineral recovery up and costs down in any mill operation. Every bubble is loaded to capacity with the desired mineral—a wide range of Xanthates makes a choice of selectivity possible: Z®-3, *Potassium Ethyl Xanthate*, is a low-cost reagent —popular as an all-purpose collector for many years.

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SINCE 1950 a motorized caravan carrying doctors, technicians, and medical equipment has been touring the Colorado Plateau checking health hazards to mine and mill workers in the uranium industry. Since the group began operations, more than 1000 workers have been checked. The caravan is staffed by U. S. Public Health Service personnel, who have been working in cooperation with the Atomic Energy Commission and the health departments of Utah, Colorado, Arizona, and New Mexico.

Field workers have scheduled 18 field clinics at convenient locations in 20 mining districts of the four states this year. Duncan Holaday of the agency's Occupational Health Field Station, Salt Lake City, is coordinating the program, with Dr. James Egan serving as physician in charge.

"We are not seeking to run anyone out of the industry," Mr. Holaday said. "The hazards are controllable, and furthermore it takes many years of exposure to radioactive materials to cause damage to human organisms."

Mr. Holaday presents European data to support his contention. Medical men on the Continent had known for years that miners in the Erz mountains died in their prime showing symptoms of lung damage. Such deaths, occurring in regions now known to be producing uranium for the USSR, have only recently been attributed to radioactivity. In addition to highlighting this kind of danger, the Health Service work is being pitched toward reducing and eliminating potential mine and mill hazards.

At this stage of investigation it has been indicated that danger from radon (radioactive gases) is less than from dust inhalation. In mills, prevention of silicosis from silica ores is as important as the radiation hazard. No clear-cut illness pattern has been established for uranium workers. But before conclusive data can be established, many more years of study can be expected.

Right now, miners are being urged to take daily showers, wash clothing often, and to employ wet mining practices.

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JOHN L. LEWIS, a man who needs no introduction—he usually makes his own, may start throwing a few choice brickbats at the Bureau of Mines, Secretary of the Interior Douglas McKay, and the Washington scene in general. Object of his latest pique will probably be the report of the five-man committee studying procedures for overhauling the Bureau of Mines. One suggestion, and the one most likely to make Mr. Lewis and the United Mine Workers Union unhappy, is that coal mine safety be taken over by the states after a period of education. Secretary McKay endorsed the idea.

A UMW spokesman pointedly noted that Mr. Lewis had not been consulted nor had the union been asked to sit on the committee. The spokesman intimated that Mr. Lewis would blast the plan sometime in the future. The mine union has for years fought for Federal mine safety laws, taking the position that education without proper enforcement will not work.

Secretary McKay did not approve another suggestion by the committee that inspectors notify mine operators the day before an inspection is started so that arrangements could be made to facilitate the inspection. The committee made several other recommendations.

It urged the Government to withdraw from helium manufacture and the plants be sold or transferred to private enterprise. The committee also felt that the Government should get out of the production of titanium and zirconium, provided such action is not inconsistent with national security. The survey team noted that any arrangement for private operations "should protect and satisfy fully the military requirements of the nation."

A recommendation was also made that the Government halt its experiments on oil from shale at the Bureau's Rifle, Colo., mine "unless there is a substantial contribution by industry under a cooperative agreement."

The team would also have work at Morgantown, W. Va., and Bruceton, Pa., on synthetic and gaseous liquid fuels from coal and lignite confined to a small scale research operation and not expanded into large pilot and demonstration plants.

The team members were: Curtis L. Wilson, dean of the Missouri School of Mines, Rolla, Mo., chairman; John C. Kinnear, Sr., former vice president, Kennecott Copper Corp., New York; Dennis L. McElroy, vice president, Pittsburgh Consolidation Coal Co., Pittsburgh; J. R. Butler, president, Butler Johnson Corp., Houston; and Spencer S. Shannon, Bedford, Pa., former director of the Materials Office of the National Security Resources Board. Target date for compliance with the team's suggestions is July 1, 1955.

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MORE than a year ago four Northern Rhodesian copper mining companies began negotiations with the Northern Rhodesia Mine Workers' Union which represents European workers, hoping that the color bar might be lowered enough to allow negroes an opportunity at more skilled and better paying jobs. In February of this year white workers at the Roan Antelope mine voted to delete from their agreement with the company the clause limiting employment in certain positions to whites. Gert Lombaard, speaking for the South African Gold Miners Union, called upon all white miners to fight the move. He also blasted a plea by Sir Ernest Oppenheimer, Anglo-American Corp., for the union to give nonwhites a chance at the higher paying positions. The latest report is that the negotiations have ended inconclusively. Formal discussions had been in progress with the Northern Rhodesia Mine Workers' Union, the Mine Officials & Salaried Staff Assn., and the African Mine Workers' Trade Union since Feb. 5.

In a statement issued by the Northern Rhodesian copper mining companies, the net result appears to be that "The position which existed at the beginning

of negotiations and still continues is that the employment of Africans in any job within the field of the European daily paid workers is, in effect, prevented by the agreement between the European union and the companies."

The impasse seems to lie in the union stand that while it has no objection to the promotion of Africans to European daily paid posts, Africans must also receive equal pay and all the conditions of service given to Europeans. Recently added was the condition that promotion must be to a complete job held by a European and that there must be no subdivision of jobs.

African representatives in the talks have made it clear, according to the copper companies, "that in the circumstances at present prevailing in Central Africa they regard this attitude as effectively maintaining the bar to their future progress."

The companies contend that some subdivision and simplification of certain European jobs is essential if African advancement is to have meaning, both in order to provide opportunities of training, and also where necessary, to bring work and responsibility within the present scope of African workers. African representatives are in agreement with this stand, it is reported. The companies also feel that subdivision and simplification imply a "need for special rates of pay."

The copper companies further argue that many of the increments accruing to white workers were born during a time when Africa was quite primitive and unhealthy, in order to attract the best European labor to the copper belt. Bonus systems, subeconomic rentals for company housing, and "every kind of amenity" were referred to by the copper companies.

The companies point out that "They are . . . fully appreciative of the anxieties which prompt the European union to attempt to impose . . . conditions on African advancement . . . [but] such anxieties can be allayed . . . by the framing of suitable safeguards to secure the position of the European employee and to ensure the continuance of that European leadership which the companies hold to be essential to the future prosperity of the industry.

"The suggestion has been made that the companies are mainly concerned with obtaining cheap labor. They wish categorically to refute this suggestion and to reaffirm that their sole desire is to find a remedy, acceptable to all parties and consistent with best interests of the Territory and the Federation, for a pressing human and social problem. It is in fact probable that no financial saving whatsoever will accrue from African advancement . . . in view of lower output of the African worker and the greater need of supervision."

SENATOR George W. Malone and his subcommittee, in a recent report, labeled false the notion that the U. S. is a have-not country. The Minerals, Materials, and Fuels Economic Subcommittee of the Interior and Insular Affairs Committee stated that "our domestic and foreign policies have been based on the false assumption that the U. S. is a 'have-not' nation insofar as the supply of critical raw materials necessary to this nation in war are concerned. It has led the U. S. to become dependent upon foreign sources across major oceans for raw materials which could be produced within the continental limits of the U. S. and within the Western Hemisphere."

Raw material reserves of the U. S. are greater than at any time in the history of the country, according to the committee. The report states that "we have consumed more than the total quantity of proven commercial reserves of two decades ago." Only financial incentive is necessary for the discovery of latent reserves through the use of modern exploration techniques, the Senators say.

The committee emphasized that mines are more easily closed than reopened. It takes years to repair the damage of floods and caving action, and men and equipment scattered far and wide have to be replaced before operations can begin again.

Behind the committee report is the fear that if the U. S. should someday become involved in a war, the far-flung sources now supplying many strategic items will not be available. The report also takes issue with international organizations whose purpose it is to control distribution of production and consumption. Such groups, the Senators state, "can only serve to inhibit our own 'going-concern' industries." Testimony before the committee supported the contention that the International Materials Conference serves only to deplete and retard fulfillment of stockpile objectives.

The report also assailed the present situation in respect to agencies handling stockpile arrangements. The committee contends that their work is largely uncoordinated, without direction or objective.

What does the committee recommend?

1. Closer economic cooperation between nations of the Western Hemisphere.
2. Increased depletion allowances to producers of critical minerals and materials.
3. Acceleration of the federal stockpiling program coordinated with the "going-concern" production industries in the Western Hemisphere.
4. Operation of a comprehensive five-year program of research into new uses and improved methods of beneficiating critical materials, financed through appropriations of at least $50 million annually.
5. Maintenance of a long-range market price for uranium produced in the Western Hemisphere.
6. Expansion of the domestic titanium goal to 150,000 tons annually.
7. Improved regulation of petroleum gas and coal resources in the U. S.
8. Repudiation of all international controls of production, prices, and supplies of critical materials.

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B44

Cyanamid REAGENT NEWS

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Anaconda First to Roast Low Grade Sulfur Ore to produce SO_2 for Acid Manufacture

The world's first commercial installation for producing SO_2 gas from low grade sulfur ore, is now on stream at Anaconda Copper Company's plant at Weed Heights, Nevada.

The FluoSolids System that makes this possible includes four 18 ft. dia. Reactors plus other Dorr and auxiliary equipment. SO_2 gas is sent to a 450 TPD contact acid plant which supplies all acid requirements for leaching 11,000 tons of copper ore per day.

Feed to the system is 650 to 750 tons per day and gas production 26,000 to 30,000 C.F.M. Gas strength averages 8 to 12% representing a sulfur recovery of 98%. Unusual? Yes, because this is the first time that low grade sulfur ore could be recovered as SO_2 . . . economically. Here's how the system works . . . ore averaging 28% total sulfur is crushed to 10 mesh and fed dry to the Reactors which operate in parallel. Once ignition temperature is reached no extraneous fuel is needed. Ore is simply fed in at the design rate, latent heat in the bed immediately brings it to ignition temperature, and the fluidizing air oxidizes the sulfur to SO_2. Shutting down is a matter of minutes. And because the fluid bed stores sufficient heat, roasting can be started again after as much as 72 hours without adding additional fuel.

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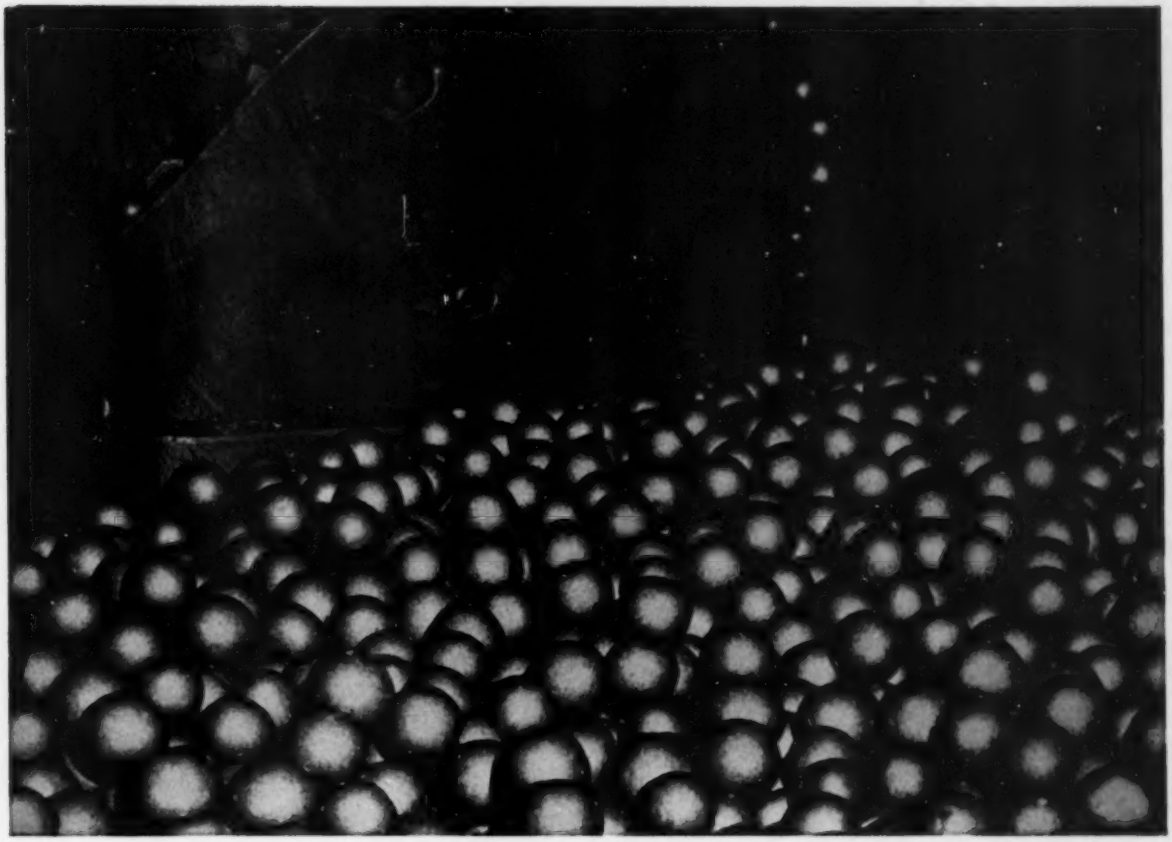

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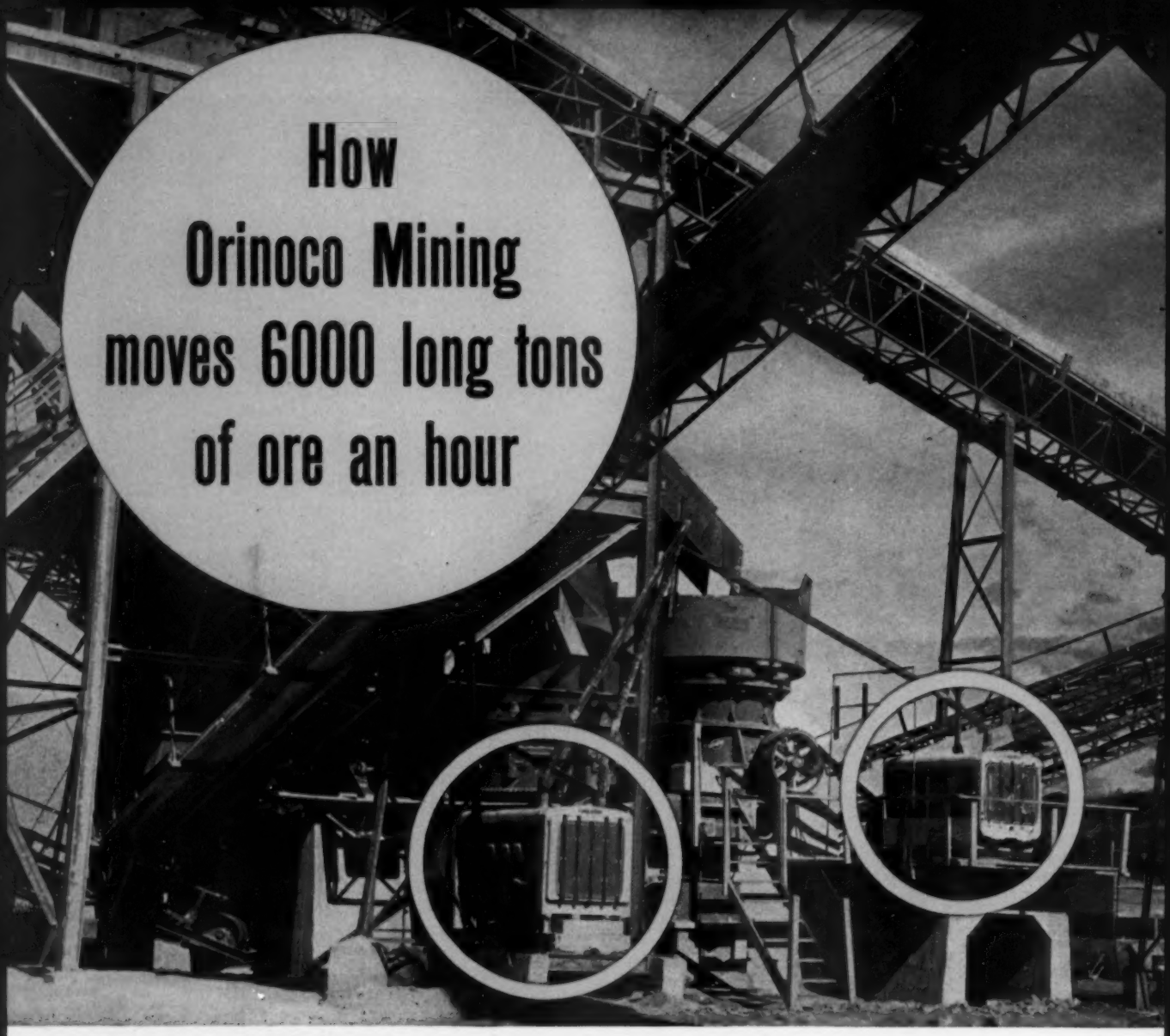

How Orinoco Mining moves 6000 long tons of ore an hour

Here are two CAT* Diesels helping crush an iron mountain. This team of D17000 and D13000 Engines drives secondary 30″ x 70″ gyratory crushers for Orinoco Mining Co. in Venezuela. A 60″ belt conveyor, traveling 600 feet per minute, delivers ore to this crushing plant from a primary crusher driven by a D364 Diesel Engine. Power for conveyor belts and lights is supplied by Caterpillar Electric Sets.

The iron is the first taken from deposits recently unearthed on Cerro Bolivar, an 1800-foot mountain packed with some 400 million tons of high-grade ore. To get this prize ore to mills, Orinoco Mining built a port to handle ocean-going freighters, put down over 90 miles of railroad and paralleling highway, and raised two complete towns. More than 150 Caterpillar units—engines, electric sets, tractors, scrapers, motor graders, bulldozers—worked on the gigantic job.

Today 6000 long tons of ore an hour—three million tons a year—move down from Cerro Bolivar. Soon shipments will total ten million tons a year. Helping move every ton are Caterpillar units like the engines in the picture. Their specially hardened crankshaft journals, long-lived aluminum alloy bearings, truly effective filters and seals, and other quality features will help keep ore coming from Cerro Bolivar for years. And they'll do it economically, too: Caterpillar-built fuel injection systems let all Cat Diesels deliver full power on low-cost No. 2 furnace oil.

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MODERN HEAVY-DUTY POWER

Drift of Things

FALL meetings and football are in the air. Kick-off for the round of AIME fall meetings comes at San Francisco when MBD gets together for an interesting program following the Mining Show. Jumping across the country finds Industrial Minerals meeting at Lake Placid October 6 to 9. Then at the end of October the Coal Div. participates in the AIME-ASME Joint Fuels Conference scheduled for Pittsburgh this year.

Last but not least, planning for the inaugural Rocky Mountain Industrial Minerals Conference at Salt Lake City has the Utah Section busy. It is hoped that this meeting will join the ranks of conferences now regular fixtures in the fall meeting fare. Only group not specifically sponsoring a divisional meeting this year is MGGD, even though members of the division are cooperating in those being held. MGGD now aims to build up its regional and section meeting first, but perhaps will join the bandwagon next year. *(See AIME section for programs of the meetings.)*

RECENTLY Walter J. Murphy, editor of *Industrial & Engineering Chemistry*, took aim at a glaring evil. No roundhouse blow, it was, in fact, too apt to pass by and too tight to paraphrase. Here are some extracts from his column:

". . . Through the years an insidious form of merit determination has been woven about us all. It is the judging of a scientist's merit by papers and patents —the sheer physical number—for which he has credit. We have been aware of this in a general way; so have thousands of others. But we were set back on our feet and rocked a short time ago by a plain statement from an author to a proposal by us. To save space, we had suggested combining three of his papers, related in subject matter, under a single title and authorship. This is what he said: 'We are anxious to have *three* papers, not *one*. We would have obtained this situation quite readily if we had not submitted each of them separately. It appears to us, however, that it would be proper to have the three papers appear together. Unfortunately, the fact remains and no doubt will remain for a long time in job applications for our graduate and post-graduate men, that the number of papers a man has is important.' We do not recall that any author has been quite so blunt before. We do not blame this professor particularly—he is caught in the same web as hundreds of others. But we do find fault with the system that has led to the establishment of such artificial standards.

"It is true that research is part of the lifeblood of good teaching. Results of research which are significant should be published, for otherwise they are of value only to the men doing the research and others with whom they have personal contact . . . Five articles on various phases of a continuing piece of work may add up to an impressive total of pages. But each must repeat to some degree material presented before. In the long run, perhaps two articles, at the end of the work, would have done the job adequately and made reference easier. We do not mean to imply at all that publication should be held up until the bitter end of a research project. This may lead to the other extreme—failure to report at all, leaving the research of little value except through the education of the men who did it or through transmission of the information by means other than publication. Publication of some of the results may save the repeating of some of the work or may lead to valuable suggestions. We *do* deplore the piecemeal papers which accomplish nothing more than to raise the total of an individual's published work."

Amen. It happens in AIME, too.

AND then Mr. Murphy took a swing at a lesser evil, one of the irksome variety:

"Flowers for the living are fine. Acknowledgments of assistance are a form of this commendable practice. But acknowledgments can be like medals. They mean little, if everyone receives one. We note—with concern—an increasing tendency on the part of authors to acknowledge the aid of anyone remotely concerned with research projects reported. We do not consider such blanket bouquets of much value. We do not think that a colleague who has made minor suggestions about a piece of work, or about the organization of a report on that work, expects thanks in print. We urge authors to acknowledge where aid is substantial, and then to state plainly what shape the aid took. All will benefit." Again. Amen.

LITTLE did we realize back in 1951 when we had the exclusive story on the Cavitron method of ultrasonic machining of hard metals, that the development would take the turn that it did. We have just come across articles pointing out the development and application of the Cavitron machine to "virtually painless and almost noiseless" dental drilling.

Not the least of people we cannot stand are dentists, including the so called *painless* variety. Perhaps we would have done well to discourage the makers of this infernal though efficient machine, perhaps even to sabotage its earlier models. And yet, if current reports are accurate, the way for a truly painless dentistry may have been paved, and we will be able to look back happily to the original article in which the ultrasonic method was found efficient and practical for drilling and shaping hard materials. We might even get so we could pass a dentist's office without shuddering!

WE have long been familiar with the extracurricular exploits into the fields of dining and dancing of one of our AIME members. A report was carried by E. H. Robie in *Drift of Things* in the September 1942 issue of MINING AND METALLURGY, and we carry a copy of the latest booklet on dining out in Manhattan that this expert puts out. Recently an article was published in the *New York World Telegram and Sun*, in which our associate in AIME is given the name of Professor Pi. It was a delight indeed to be able to see behind the anonymity, and recognize Dr. Robert Sosman, professor of ceramics at Rutgers University.

Dr. Sosman has been publishing his booklet entitled *Gustavademecum for the Island of Manhattan* for a good number of years, and the demand for copies has been so great that he has been forced to make a nominal charge (50¢ per copy, three for $1) to cover his printing expenses. (A.S.C.)

Ore in '54

Quebec-Labrador Ships Iron Ore A Year Ahead of Schedule

The area between Ungava Bay and Sept Iles was once called "the land that God gave to Cain." It is an unhappy and unpretty stretch of country, with gaunt, silvered skeletons of burnt spruce haunting the skyline. Timber grows even more sparse as one travels farther north. There is little that is green and except for the gray caribou moss there is little cover. Everywhere is water. This is the region where Iron Ore Co. of Canada has already proven some 417 million long tons of ore with an average analysis of 59.53 pct. Many other orebodies are still to be drilled. Deposits containing less than 50 pct iron are not included in reserves, although tremendous quantities of the lower grade ore are available. *(See article in* MINING ENGINEERING, *April 1954.)*

Visitors to the country have been few since the time of Jacques Cartier in the 1530's. Roman Catholic missionaries often touched around the rim of the long northeast coast that runs from the Gulf of St. Lawrence to Ungava Bay, but not until 1900 did the significance of this forbidding land penetrate to the outside world. That year, Albert Peter Low, a geologist for the Canadian Government, wrote a magazine article which began: "The present high value of iron and steel, and the consequent activity in the search for and development of new sources of iron ore make this a fitting time to call attention to the iron-bearing deposits of the Labrador Peninsula." Three things were missing for development—fuel, power, and a railroad.

In 1929 Canadian geologists discovered iron ore and mapped ore showings. In 1936 the Labrador Mining & Exploration Co. was formed by Canadian interests. The Hollinger Consolidated Gold Mines Ltd. obtained an option to purchase control of the exploration group and also formed a new group, Hollinger North Shore Exploration Co. Ltd. M. A. Hanna joined forces with Hollinger in both exploration companies. By 1945, 12 deposits containing 160 million tons of iron ore were discovered—backing Low's early observations. There was no doubt that the ore was there —but it was some 320 air miles from tidewater on the Gulf of St. Lawrence.

THE SHIPS: Loading facilities at Sept Iles include 5000-ton mixing bins at lower right. Townsite shows at upper left, with oil supply tanks at center.

It was evident that the financial resources of any one company could not handle the project. The original Canadian concession companies and Hollinger Consolidated Gold Mines, under the leadership of Jules R. Timmins, joined with Republic, National, Armco, Youngstown, Wheeling, and Hanna to form Iron Ore Co. of Canada. With George M. Humphrey as its head, the new company took over the job of raising the money, opening the country, and developing the ore. In addition to the financing provided by the partners, 19 American and Canadian insurance companies agreed to lend $150 million. On Oct. 2, 1950, a small steamer tied up at the old village pier at Sept Iles and unloaded the first construction equipment. J. H. Thompson is now Iron Ore Co. president.

In four years the builders had to lay 357 miles of mainline railroad and construct the terminal yards; operate and maintain the largest civilian airlift in history; build and maintain base camps and way stations to house and feed 6900 men; construct dock facilities at Sept Iles large enough to receive raw materials as they arrived and to ship at least 10 million tons of ore a year; plan for and start construction of two new townsites to house permanent employees; build two hydroelectric plants and transmission lines; and prepare open pit mines for operation, constructing, crushing, screening, and loading equipment.

Muskeg country, bitter winters, and mountains harried construction. Yet, in December 1953, working out of the ultimate railroad midpoint known as Oreway, track laying crews made more than two miles per day on 10 straight days in −30°F weather.

Shipping season at Sept Iles is expected to be between 200 to 240 days, and as many as six or seven ships will be loaded per day. Seven or eight million tons of ore will go by deep-water routes to Atlantic Coast ports. The rest will be transshipped to Great Lakes ports in carriers small enough to negotiate present canals along the St. Lawrence. When the Seaway is completed it will be possible to ship huge tonnages through an inland waterway, providing maximum protection during time of war. With the inaugural ceremonies at Sept Iles the operation started production about one year ahead of schedule.

Drilling Practice—

Five Years of Revolution

MODERN mining is based on drilling—everything else stems from that. U. S. and Canadian mining companies and suppliers of mining equipment are constantly seeking new techniques and tools for increased drilling efficiency. Ultimate goal is increased bit-against-rock time. Just how important their efforts are can be seen through a legitimate extension of available statistics. In Canada some 70 million ft of drilling per year is required. While the number of feet actually drilled in the U. S. is unknown, it is possible to compare U. S. and Canadian mineral production, excluding oil and coal. In the U. S. mineral value was $4200 million and across the border $836 million. Taking into account the number of drilled feet required to produce Canada's total, the U. S. total would be 365 million ft in 1953. A saving of 1¢ per ft would reduce overall metal and nonmetal mining costs some $3.65 million per year. This does not take into account other indirect savings.

Methods have changed and there have been structural and metallurgical advances in blasthole practice in the last ten years. The Editors of MINING ENGINEERING in the articles on the following pages present the most significant innovations coupled with results in the field. Environment plays an important role in selection of materials and equipment —but while unanimity does not exist throughout the industry in reference to drilling problems, a definite trend is evident. For the story of that trend read the articles on the following pages.

Edited and compiled by the staff of MINING ENGINEERING.

Homestake Swings to Light, Portable Equipment

by C. N. Kravig

Following the idea, seek and you shall find, Homestake has changed its drilling methods and equipment in the last few years to reap the benefit of increased production and lower costs.

AFTER several years of testing, Homestake has adopted tungsten carbide bits for all drilling in drifts, raises, and stopes. This type of equipment has been used exclusively in drifts and raises for three years and adopted in stopes for two years. Changes are still being made and research is a constant part of efficient drill practice. New types and grades of tungsten carbide, smaller bits (1¼-in.), more study of integral tungsten carbide bits, alloy rods, and improved drills all call for additional testing and study.

Early Drilling Equipment

Until a few years ago, all primary drilling equipment consisted of 3½-in. drifters and 3⅛-in. stopers. One-in. quarter-octagon integral forged drill rods were used for development and stoping.

Forged steel was replaced by one-use steel bits in combination with 1-in. quarter-octagon drill rods. This change was made after extensive testing of the one-use type bits as well as multi-use steel bits. The single-pass bit reduced drilling costs considerably by eliminating the expense of repeated handling of more than 3000 pieces of forged drill rods daily. The personnel of the drill forge shop was also reduced from 34 to 14 men, which constituted a considerable gain in itself. The major difficulty experienced with throw away type bit was removal from the drill steel.

This change to the one-use steel bit did not produce any significant change in the drilling speed over the integral drill rods. The average was about 10 to 12 in. per min.

Present Drilling Equipment in Stopes

Several years of testing has shown that tungsten carbide bit life and drilling efficiency depends on the correct rock drill, drill rod, rotation, air pressure, and hardness of the carbide insert. The most satisfactory drill package for Homestake stoping has proven to be 1⅜-in. tungsten carbide detachable bit with a 2⅝-in. bore jackhammer with nontappet construction and fast (1:28) upstroke rotation. Drill steel is ⅞-in. hexagonal carbon steel. The drill combination is operated from a pneumatic feedleg.

For maximum results at Homestake, a lightweight, hardhitting machine is needed for use in the jackleg setup. Fast upstroke rotation was necessary to keep the bits tight on the drill rods, prevent thread damage, and maintain drilling speed. A larger machine increases drilling speed, but is heavy to handle for difficult setups.

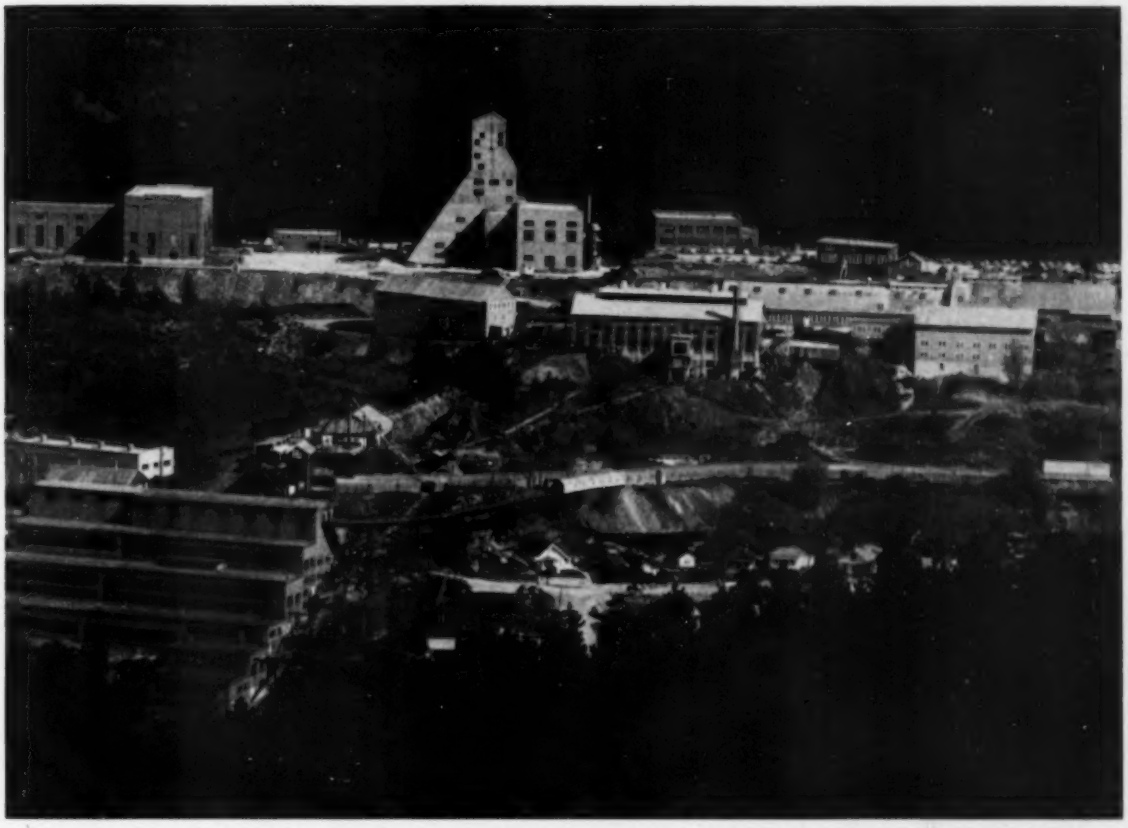
The new lightweight equipment with small tungsten carbide bits has increased production materially. In shrinkage stopes, where the broken rock presents irregular setups, previously used column mounted drills required staging or digging for proper headroom. Setting up and tearing down under these conditions required at least 30 min. Consequently, one setup with an average of five or six holes made the work for one shift.

Now, sinkers mounted on pneumatic legs make several setups possible during a shift and permit drilling in tight places without digging out. Special holes and test drilling is accomplished without excess effort. The total footage drilled in a shift has increased over 50 pct and contract earnings have improved substantially with less physical exertion.

After years of test work and correlation of the data obtained, Homestake has switched to the light drill machine, small insert bit, and small drill rod. Increased production and lower costs are the result. Here are advantages that the Homestake management feels have been derived from this change.

1. **Substantially higher efficiency in tons per man shift in stopes and feet per man shift in development headings.**
2. **Greater drilling speed.**
3. **Greater mobility.**
4. **Lighter weight equipment in stopes with less strain on men.**
5. **Lower air consumption.**
6. **Explosives savings.**
7. **Lower capital investment per stope.**
8. **Lower nipping costs.**
9. **Lower cost for racking and distributing bits.**
10. **Lower tonnage of dull steel in circulation.**

C. N. KRAVIG is Mine Superintendent, Homestake Mining Co., Lead, S. D.



General view of the Yates Shaft group of the Homestake Mining Co., Lead, S. D. Drilling has played an important part in the successful exploitation of the major gold deposit.

Breakage and powder efficiency have improved because drilling can be more selective with an improved pattern to give uniform burden on the hole from the collar to the bottom. Other notable improvements have been 50 pct reduction in air consumption and slightly lower explosives cost per ton of ore.

The same drill is used for both primary drilling and blockholes. Where a square-set stope was equipped with two 3½-in. drifters and necessary accessories along with a jackhammer for blockholing, it now requires only two lightweight sinkers with airlegs. This represents a 58 pct decrease in capital investment for stope drilling equipment.

Drilling Conditions at Homestake

The Homestake orebody occurs as a replacement deposit in highly folded Pre-Cambrian metamorphic rocks. The folds are tight isoclinical folds with dips of 65 to 70° and a plunge of about 35°. The rock varies from relatively soft biotite schist country rock to medium-hard cummingtonite schist in the Homestake ore bearing formation, and to hard quartzite, rhyolite, or vein quartz. The ore occurs as a replacement of the Homestake formation with sulphides, chlorite, and considerable vein quartz. Due to the tight folding, the character of rock in a crosscut may change every few inches from the softest mica schist to the hardest quartzite.

Development Drifting

In development headings, 3½-in. drifters, column mounted are still in use. For drill steel, 1-in. quarter-octagon is standard equipment. However, tungsten carbide bits perform the cutting, with 2½-in. bits for the four center holes and 1⅝-in. for the remaining holes. The increased drilling speed resulting from use of carbide bits, together with the large center, has permitted use of a longer round in the standard 7x7-ft drifters and speeded up advance considerably.

Previously, a 6-ft advance per day was customary with blasting being done in two or three stages to insure that the cut had broken enough to blast the rest of the round. A 7x7-ft drift heading is advanced 8 ft per round now with one blast. This reduces the dust hazard materially.

Recently, three headings have been driven with airleg mounted jackhammers ⅞-in. hexagonal drill steel and 1⅜-in. bits as used in the stoping. Results to date are satisfactory and this lightweight equipment may well replace drifters in the near future.

This equipment has increased advance from one 8-ft round per day in an 8x8-ft drift to 16 ft per day.

Raising

Standard equipment for raising is the 120-lb stoper drill with 1-in. quarter-octagon steel and 1⅝-in. insert bits. The use of tungsten carbide bits

Miners are driving an 8 x 8-ft arched drift with airlegs and sinkers. This equipment has improved advance rates in drifting on the 4850-ft level of the Homestake operation. Note the steel ladders on the floor to support the feed leg.

for raise rounds has increased efficiency to the point that a longer round cycle can be completed in an 8-hr shift.

Drill Steel

Forging and heat treating of collared and threaded ⅞-in. carbon steel rods has been perfected to the point that steel breakage represents true fatigue. Since the adoption of fast rotation drills thread life has been good.

With mounted machines it is necessary to maintain drill rods in lengths and sizes that are multiples of the change length of the machine, but with the pneumatic leg setup, this is not necessary. This feature permits more flexible use of the drill steel, with less waste and lower tonnage in circulation.

Alloy rods and integral tungsten carbide drill rods are still in the picture. However, the difficulty of handling full length rods as in the days of integral forged steel is revived. Alloy rods have been showing good indications for the jackleg drilling and are receiving due consideration.

Comparative Costs Per Ft Drilled

One-Use vs Carbide Bits

(Total Costs Including Overhead, Warehouse Handling, New Drill Steel, and all Operating Charges on Rod Maintenance and Bit Grinding)

Cost					
1951			1953 (7 months)		
One-Use Type A	One-Use Type B	One-Use Type C	Tungsten Carbide 2½ in.	Tungsten Carbide 1⅜ in.	Tungsten Carbide 1⅜ in.
0.058	0.056	0.078	0.187	0.104	0.074
Average Footage Per Bit					
5.6	4.8	4.2	182.1	181.2	285.8

Sinker Drill-Pneumatic Leg Use Substantiates Proponents

HERE we are quoting a private company report made in April 1950 regarding testing of the combination setup. At this time, the sinker and pneumatic leg was not widely accepted in the U. S. although considerable testing was underway.

As indicated by C. N. Kravig, total investment in equipment is lower, and this report from a large Western operation gives this idea further confirmation:

According to various current mining publications and some contact with other mining organizations, there is a marked change occurring in rock drilling. A number of mines are testing or using a jackhammer mounted on a pneumatic leg with a standard drill rod and detachable tungsten carbide bits. This method is being used in mines where drilling is as difficult as here and they are finding that satisfactory service is given at a lower cost.

It is believed that the broken, ravelly ground will not cause difficulty, because a four point bit is used. The machine is not as powerful as a large drifter or stoper, so that sticking steels should not present any severe problem.

The main use for this type of machine would be drilling where a stoper is now used. Some mines claim that 60 pct of all stoper work will be or has been replaced with the jackhammer and pneumatic leg. One advantage to our using this setup would be the ease of handling, since it is in two parts, the heaviest being not over 64 lb, depending upon the size of jackhammer used. Also, a large jackhammer has 40 pct less air consumption than the stopers now being used. The net result of the smaller equipment and lower air consumption is somewhat slower drilling speed. But savings in man hours, steel and bits, and auxiliary equipment reduces total cost per man shift sufficiently so that the cost per foot of advance is lower.

In addition, we have found that small tungsten carbide bits do not give the service that larger bits do, but the claims are that this lighter equipment greatly increases bit life and this combined with the reduction in steel costs could be a very substantial gain.

The comparative data is given on a 3⅛-in. stoper and a 2⅝-in. jackhammer with pneumatic leg:

	Stoper	Sinker
Weight—Drill	116 lb	64.5 lb
Weight—Pneumatic Leg	—	41 lb
Air Consumption	256 cfm	153 cfm
Length of Change	1.5 ft	—
Stoper—changes of steel necessary for 6.5 ft round (1-in. Q.O.)		
2 ft 0 in. starter	6.10 lb	
3 ft 6 in. 2nd	10.67	
5 ft 0 in. 3rd	15.25	
6 ft 6 in. 4th	19.82	51.75 lb
Jackhammer and airleg—steel changes for 6.5 ft round (1-in. hex.)		
2 ft 0 in. starter	5.38 lb	
6 ft 6 in. 2nd	17.48 lb	22.86 lb

The data given shows a marked possibility in a reduction of costs in labor, air consumption, drill rod circulating load. A 55.82 pct decrease in drill rod requirements could be made. Arrangements might possibly be made to obtain these for test purposes.

It is interesting to note that this report was written before any sinker-airleg combination had been tested at this operation. Investigations show that it was almost a year before the equipment was tried.

Sometimes the change to new equipment is slow, but rock drilling is surrounded by numerous outmoded theories that have kept the science somewhat retarded. Now these ideas are being exploded at a rapid rate and the resulting progress is obvious.

Drilling in a shrinkage stope at the Homestake mine with the pneumatic-leg and sinker combination. This equipment has reduced the capital investment for stope drilling machines substantially.

Investigations and Improvements of Drill Steel

MANY operators and suppliers have arrived at the conclusion that most of the basic problems connected with drilling machines and rock bits are an acceptable minimum. But the difficulty in drilling cycle now lies in the steel rod, the intermediate that delivers the force of the machine to the cutting edges. The finest of drilling equipment is necessarily composed of three parts, anyone of which can effectively reduce the bit-against-rock time if it is outperformed by the other two.

When the integral rod was the common drilling medium, hardness of the bit was the important factor, since breakage was less frequent than dulling. With the detachable steel bit, the drill rod performance became somewhat more significant, but the bit had to be changed every few feet, so it was still the weakest link of the chain.

However, the improved efficiency of the tungsten carbide insert bit completely altered the picture. First of all, the expense of the insert bit placed great importance on the dependability of the rod, together with the fact that a bit could drill 50 ft or better without change created considerable excitement.

Numerous manufacturers in U. S. and Canada have been actively engaged in research on this important problem. Various methods of testing and evaluating results have been devised for the different types of steels that are rolled into drill rod.

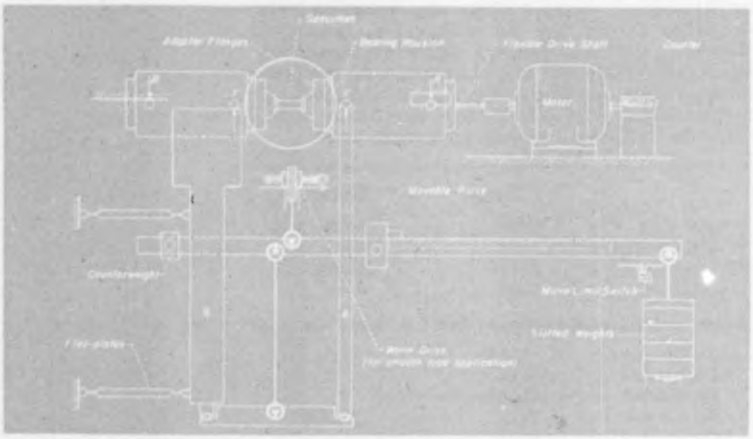
Before discussing any of the laboratory methods used for examining drill steel, it must be understood that no attempt is made to duplicate actual drilling conditions, because the operator becomes a major factor, in that it is possible for him to break the perfect drill rod in the first hole. This has no relation to what is the best alloy, best type of connection, or best heat treatment. However, with laboratory equipment it is possible to introduce the type of stresses into the material that do cause the drilling failures, and a general trend can be established.

Canadian Test Work

The Canadian Dept. of Mines & Technical Surveys has actively engaged in research on the mechanical-metallurgical features of drill steel for a number of years. Several unique methods of testing have been devised to check and determine a standard for judging the effectiveness of various alloys and treatments applied to steels.

Examinations of publications of the Dept. of Mines and the Canadian Institute of Mining and Metallurgy, written by T. W. Wlodek, research metallurgist at Ottawa, have produced many pertinent facts in drill steel investigations.

In setting up a test program, the Canadian group investigated several testing schemes and ultimately developed methods more suitable to their needs.



Mechanism of loading of 10,000-in.-lb Sonntag rotating beam fatigue machine used for research at the Canadian Dept. of Mines. The apparatus has been modified for fatigue testing of mine drill steel to reproduce stresses encountered in the field.

T. W. Wlodek in *A Method of Fatigue Testing Drill Rods* says:

The existing methods for testing drill rods could possibly be limited to the following:

(1) Direct observation of the actual performance of drill steel in mines under normal working conditions, and recording the total length of the drilled holes.

(2) So-called *block test*, in which a drill rod is mounted in a pneumatic drill and hammered against a steel plate to failure. The time required to failure is recorded.

(3) Use of the General Electric pneumatic fatigue testing machine. In this type of test, the fatigue properties of drill steel are determined by vibrating the bar with compressed air to failure. The amplitude and frequency of the vibration of the bar are measured and the number of vibrations to failure is recorded. The magnitude of bending stresses is calculated from the measured amplitudes of the deflection, and results are presented in the conventional form of S-N curves.

While the three possible methods mentioned above have some good characteristics, they possess some troublesome features and therefore it is generally felt that there is still need for a simple and cheap laboratory and workshop method for the simulated service testing of mining drill rods.

A practical method in which the mining and steel industries might be interested should:

(1) Be simple and cheap.

(2) Stress the mining rod similarly to the conditions met in the mine, both as to the type of stresses and as to frequency.

(3) Permit the performance of tests under dry conditions and under water corrosion conditions.

(4) Provide a simple and reliable method of measurement and regulation of stresses.

(5) Be noiseless, or at least quiet, in operation.

Based on the principles necessary for satisfactory testing apparatus, a 10,000-in.-lb Sonntag rotating beam fatigue machine was selected. This has been used to correlate the relative merits of the types of drill steel as well as the methods of treatment.

But like any method, this machine is not universally accepted as a testing apparatus. In fact, a wide variety of schemes are used by makers of drill steel and research organizations. It is the hope of those engaged in developing better drilling equipment that some standard method can be adopted. Numerous opinions are available on the best system. Quoting from *Modern Trends in Hollow Drill Steel* by H. M. Hamilton of Atlas Steel Ltd.:

One of the first methods used by the steel maker for testing of drill steel was the block test. A given length of the rod to be tested is placed in a pneumatic drill and hammered against a hardened steel plate to failure. The results of these tests have been found to be erratic and, to our surprise, the plain carbon rods give longer runs than the alloy steels. This variation in test life was found to be primarily associated with the damping characteristics of the rod itself. The higher the damping capacity, the less does the rod vibrate when striking the face plate; thus, the less is the amplitude of stress created in the surface of the bar. As a result of this condition, the plain carbon steel having high damping capacity, is found to run three or four times the life of the nickel alloy drill steel which has a much lower damping power. Yet actual performance tests in mine drilling prove the alloy grade to be superior and to provide at least three to four times the life of the carbon steel.

It is, therefore, apparent that the block test could not be considered as a criterion of drill steel performance in the field. However, despite this irregularity, the

Relative Strength of Drill Steel

	CIRCULAR			HEXAGONAL				QUARTER OCTAGONAL			
	¾-in.	⅞-in.	1-in.		¾-in.	⅞-in.	1-in.		¾-in.	⅞-in.	1-in.
I_c	.0152	.0283	.0487	I_c	.0190	.0354	.0597	I_c	.0219	.0432	.0756
I_f	.0152	.0283	.0487	I_f	.0190	.0354	.0597	I_f	.0217	.0427	.0750
Z_c	.0406	.0647	.0974	Z_c	.0439	.0703	.1030	Z_c	.0484	.0825	.1230
Z_f	.0406	.0647	.0974	Z_f	.0506	.0810	.1194	Z_f	.0580	.0980	.1500
A	.3798	.5393	.7230	A	.4260	.6050	.8060	A	.4645	.6670	.9020
Z_c/A	.1070	.1200	.1340	Z_c/A	.1030	.1170	.1270	Z_c/A	.1040	.1230	.1360

I

I — MOMENT OF INERTIA
I_c — (ACROSS CORNERS)
I_f — (ACROSS FLATS)

Z

Z — SECTION MODULUS
Z_c — (ACROSS CORNERS)
Z_f — (ACROSS FLATS)

A

A — CROSS-SECTION AREA IN SQUARE INCHES.

block test provides a satisfactory means of comparing various heats of the same grade. In this capacity, it functions as a control test for maintaining a given standard of quality. It has also given the steel maker a valuable tool for studying the effect of various processing methods on the ultimate operating properties of the finished drill steel bar.

A newer type of fatigue testing is the pneumatic vibrator. Compressed air is passed through a trombone to produce a high pressure wave, which impinges on a piston, alternately striking the end of a given length of drill steel bar causing it to vibrate. The bar itself is clamped in such a manner that it vibrates freely at its own natural frequency until it breaks.

The vibrator provides a useful type of laboratory test by which we can accurately evaluate those physical properties of the drill steel which are of importance to service in the field.

First of all, the amplitude of vibration can be measured and controlled so that we know the magnitude of stress occurring at the surface of the bar. For example, if a ⅞-in. hex. rod vibrates through 0.500 in., the calculated surface stress will be 73,400 psi. The same amplitude of vibration on a 1-in. hex. bar will result in a surface stress of 82,600 psi.

Method of Correlating Laboratory Data

In a paper presented to the Canadian Institute of Mining and Metallurgy at its 1954 annual meeting, T. W. Wlodek of the Canadian Dept. of Mines brought out several interesting points in the investigation of drill steel failures. Mr. Wlodek was able to establish a relationship between actual drilling and laboratory testing. Although not entirely valid, the laboratory data can be successfully applied to field problems.

From his article *Mechanical-Metallurgical Improvements in Drill Steel:*

To simplify the studies on the field performance of different types of drill sets it is desirable to have available simple working relations between the drilling machine, drill set, and ore or rock characteristics, especially one from which simple factors can be established to evaluate and analyze the existing working stresses in the drill set.

Beginning with the drilling machine, it is proposed to judge the performance of this mining element by the impact energy of a single blow marked (E).

The value of E could be determined in several different ways.

1. By direct measurements.
2. By calculation using:

(b) $E = V \times S \times P \times \alpha$

where:

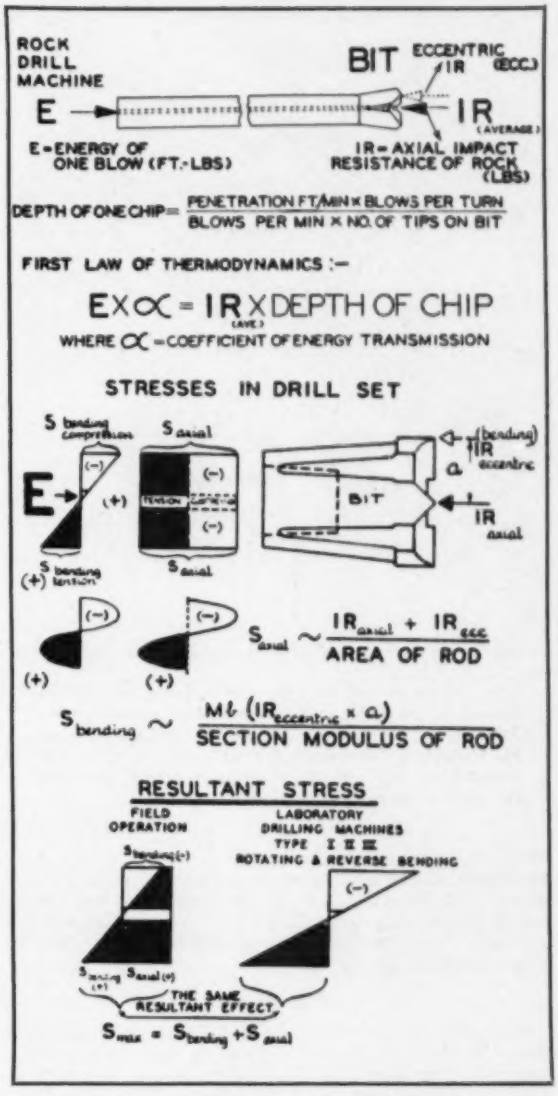
V = volume of the cylinder, cu in.
P = air pressure, psi.
S = work stroke of piston, in.
α = practical coefficient which accounts for all essential factors involved in the machine.

The estimated value of α set up from various data obtained from the manufacturers of drilling machines is approximately:

$\alpha = 0.42$ for sinkers
$\alpha = 0.50$ for stopers
$\alpha = 0.53$ for drifters.

Having established the values of E either by direct measurements or by calculation, using the method outlined by E. Wells (Australia) it is possible to establish relations between E, i.e., the size of drilling machine used and the characteristic of ore or rock drilled.

The drill set is composed of shank-end, drill-rod attachment and bit. One side of this drill set is exposed to consecutive blows of a drilling machine, each blow having an impact of E expressed in foot-pounds of energy; the other side is subjected to the reaction (IR) of the drilled rock or ore in pounds.

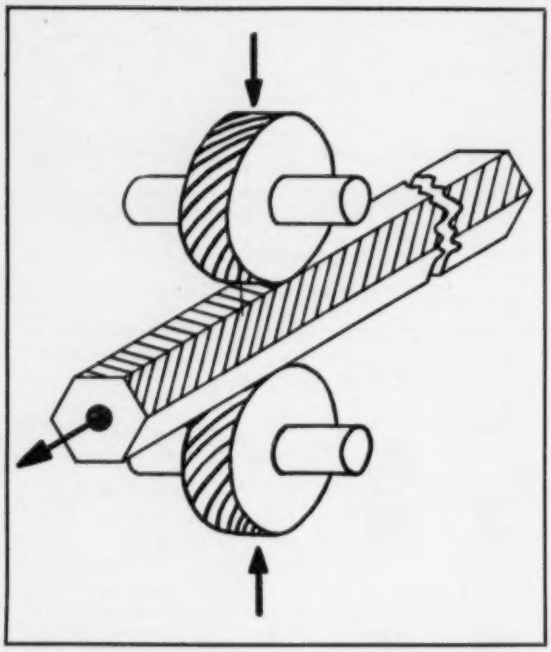

ROCK DRILL MACHINE
BIT
ECCENTRIC IR (ECC.)
E
IR (AVERAGE)
E = ENERGY OF ONE BLOW (FT.-LBS)
IR = AXIAL IMPACT RESISTANCE OF ROCK (LBS)
DEPTH OF ONE CHIP = PENETRATION FT/MIN × BLOWS PER TURN / BLOWS PER MIN × NO. OF TIPS ON BIT
FIRST LAW OF THERMODYNAMICS :-
EXα = IR (AVE.) X DEPTH OF CHIP
WHERE α = COEFFICIENT OF ENERGY TRANSMISSION
STRESSES IN DRILL SET
S bending compression
S axial
(bending) IR eccentric
a
BIT
IR axial
S bending tension
S axial
S axial ~ IR axial + IR ecc / AREA OF ROD
S bending ~ M (IR eccentric × a) / SECTION MODULUS OF ROD
RESULTANT STRESS
FIELD OPERATION
LABORATORY DRILLING MACHINES TYPE I II III ROTATING & REVERSE BENDING
THE SAME RESULTANT EFFECT
S max = S bending + S axial

Shown above is the mathematical relation of the energy introduced by the drill machine and the resistance encountered by the bit. This is a clear illustration of how the laboratory testing approaches actual field service.

This illustration of the evaluation of dynamic stresses in the drill set helps substantially in studying and in discussion of the mechanical and metallurgical improvements in mine drilling.

The laboratory drilling machines provide a useful and practical means of examining and studying the possibilities of improving the field performance of the drill set, particularly the attachment and shank end which compared with the drill rod, as such, possesses lower endurance strength and comparatively shorter drilling life.

Results of the performance as obtained on the laboratory drilling machines provide us with endurance strength values under dry and water corrosion conditions for different types and shapes of drill rods and attachments. As soon as they are available these data are given to the interested mining and metal indus-



Spiral rolling of drill steel has proven to be an excellent method for producing residual compression stresses on the rod surface. This simple treatment is effective in eliminating the troublesome "metallurgical notch" encountered in heat treatment of drill rod. Shown above is general procedure for applying the pattern to the drill rod.

tries. It is no longer necessary to estimate the performance of drill steel since it is given in psi and number of cycles to failure or in terms of IR of ore (mining and operating conditions) and time-of-drilling. In a similar way the performance of different types of attachments is given.

Drill Steel

The relative resistance against bending and direct stress loading of different sections of drill steel is illustrated in the accompanying table where the section modulus across corners of the cross-section area (Zc) was selected as a characteristic figure for the field performance in bending of circular, hexagonal and quarter-octagonal drill steels.

Mechanism of Failure In Dry Fatigue

The mechanism of failure of drill rods in dry fatigue can be simply explained as follows:

Drill steel, a polycrystalline material, under a load of sufficient magnitude deforms plastically (permanently) by slip in regions where the resolved shear stress exceeds its elastic limit. In these regions, during the cycling stressing of metal the progress of slips marked by the mobility and increase of existing dislocation causes the hardening of metal and builds up internal microstresses.

The slip planes under further cyclic loading increase in width and *ultramicrocracks* are formed and at the same time, the ability of the metal to continue in crackless plastic deformation is gradually exhausted.

In conditions where the working shear stress is large enough (where loads exceed the fatigue limit) the ultramicrocracks increase in size and grow into a fatigue crack which is generally identified as the nucleus of fatigue.

When loads are below the critical, e.g., below fatigue limit, the hardening effect stops further plastic deformation and the drill steel does not fail.

Drill rod, in the as-rolled condition, has a large number of imperfections of metallurgical and geometrical origin on its surface. These small sharp rooted notches introduce considerable stress concentrations and usually at one of these locations the intensive localized plastic deformation starts and a fatigue crack forms usually in the direction perpendicular to the maximum tension stress.

This mechanism of failure in fatigue gives an explanation of the brittle failure of metal in fatigue, and the existence of the fatigue limit.

Mechanism of Failure In Corrosion Fatigue

The mechanism of failure of drill steel exposed to tension-compression stresses and the simultaneous action of corrosive media could be presented as follows:

In general, this mechanism is similar to that in dry fatigue, but a few important additional factors accelerate the progress of fatigue in the corrosive mine water. First, it is interesting to note that the most important factor in corrosion fatigue is the effect of the adsorption process or Rebinder effect, on the fatigue crack formation. Later on, as further growth and propagation of the cracks continue, the corrision process, itself, hastens the failure of the element.

Rebinder and his associates suggested in a number of papers, and proved in numerous laboratory experiments, that a very small amount of active substances added to liquid which surrounds a polycrystalline sample under tension load, reduces substantially the stress at which the plastic flow starts. It was proved that the Rebinder effect is based on the penetration of the active surface medium deep into the inside of the strained single crystals through submicrocracks along slip planes. This effect lowers the free energy of the surface and reduces the hardness and other mechanical properties. It is responsible for the premature formation of a large number of surface corrosion cracks usually in a perpendicular direction to the maximum tensional stress.

In addition to the Rebinder effect in cyclically stressed metal, the rate of the corrosion fatigue process is largely dependent upon the corrosion mechanism which, in turn, is accelerated by the cracking of protective films of corrosion products and by the anodic behaviour of fatigue microcracks caused by large stress concentrations at the root of the crack.

Spiral Rolling and Pattern Rolling

This method [spiral rolling] is based on the creation of locked-in residual stresses through the introduction of mainly plastically deformed regions adjoining regions practically elastically deformed. The transition between these two regions may be gradual or abrupt, and the maximum of the built-in residual stresses is perpendicular to the direction of the plastically deformed regions.

In general, the object of this method is to increase the physical properties of the metal, mainly fatigue and corrosion fatigue, by rolling or otherwise impressing grooves or depressions of various patterns and shapes on the surface of the treated elements.

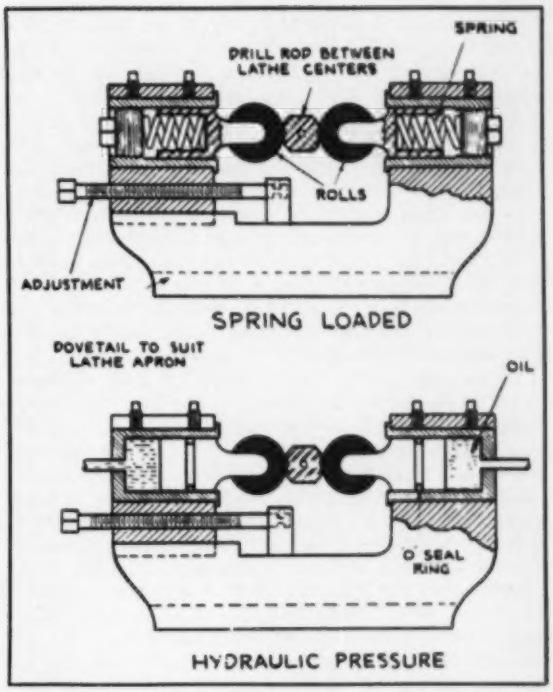
As a result of the pressure applied to make these depressions, the metal in these regions is substantially all plastically or permanently deformed. The metal in the untreated regions remains substantially in its original elastic form. The mutually interlocking stresses created in this way are responsible for the great increase of the physical properties of the structural element treated by this method. When pressure is applied to the whole surface of the metal element the mutually interlocking stresses produced by the described method are not developed. From the results obtained in the laboratory tests on spiral-rolled drill steel and drill-rod attachments, sufficient data are available to recommend various patterns of this treatment for the exploratory use by the mining industries.

From the approximate evaluation of the locked-in compression stresses as built up by spiral rolling, it was observed that the principal maximum compression stresses are in a perpendicular direction to the pattern. The locked-in compression stresses in the parallel direction to the impressed pattern are about 50 pct of those in the perpendicular direction. From the conditions assumed and given in Fig. 8, spiral rolling as compared with shot peening is about 37 pct more effective.

Endurance Test Data of Drill Steel

1-in. Quarter-Octagon Cr-Ni-Mo Steel

Bending Moment, in.-lb	Maximum Stress psi	Cycles to Failure		Endurance Factor
		Untreated	Spiral Rolled	
7,000	57,500	350,000	over 6 million	over 17
8,000	65,800	282,000	over 6 million	over 21.5
9,000	74,000	80,000	over 6 million	over 75



RIGHT—Two types of lathe attachments for spiral rolling of drill rod. Either of the two appliances can be adjusted to give the desired pressure on the rollers. These attachments are designed to fit on the bed of a turret lathe.

Longhole Drilling at Holden Mine—

Greater Productivity, Lower Costs

by J. J. Curzon

WHEN the Holden mine went into production early in 1938, mining methods seemed to be firmly established with conventional steel in development and exploration headings, powder blasting for ore breaking, and bulldoze chambers and long wing raises for ore gathering. Nobody at that time visualized any radical changes in the near future, although the possible use of detachable bits was beginning to create some interest then, but several important changes did come with the passing years. Some changes were brought about because of the need to maintain uninterrupted production during the war years under decreasing manpower; while others were directly due to technical advances made in the mining industry.

The original system using bulldoze chambers and long wing raises for ore gathering was replaced by 50 hp electric slusher installations placed back-to-back wherever practical. At first, these slushers were used in conjunction with relatively short ore passes and loading chutes. Later on, slushing directly into cars was used successfully. Most recently, mucking directly into cars has been used to advantage. Thus, three practical and proven methods are now available and the conditions at each individual stope determine the system that will be adopted.

Drilling in development and exploration headings passed through a series of improvements from hand crank machines and conventional steel; next came the one-use or throw away bit; and finally the present combination of tungsten carbide bits and automatic machines mounted on jumbos with long chain feeds became standard.

This advance in drilling equipment and technique has resulted in some rather startling savings. Tonnage of drill steel in the circuit has been reduced an estimated 75 pct for the equivalent amount of drilling, which means lower nipping costs all along the line. Steel shop crews have been cut from an average of ten man shifts per day to about two shifts per day, which represents another distinct saving. Drilling speeds have increased from an average of 6 in. per min in 1937 to 1938 to 19 and 20 in. per min in 1950 to 1951. No records are available

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for this factor prior to 1941, but from 1941 to 1943, when the multi-use detachable bit was used chiefly, an average of 16.3 ft of hole per drilling hr was attained, but in 1951 this factor was 31.79 ft per drilling hr. This is an improvement of about 95 pct.

The net result of increased drilling speeds with less physical effort on the part of the miners has been to increase the feet per man shift appreciably. Two men using old equipment in a 7x7-ft drift years ago would require all day to drill out a 5½-ft round. The combination of long shells, tungsten carbide bits, and jumbos equipped with two automatic drills mounted on 8-ft chain feeds, however, cut drilling time for a 7-ft round to 1½ to 1¾ hr, including setting up and dismantling.

As a result of experiments begun in 1940, diamond drill blastholes had replaced powder blasting for ore breaking by 1944. A few years later, the successful use of tungsten carbide insert bits in development headings, plus the fact that diamond costs were steadily increasing to an alarming degree, caused research to be started investigating the possibility of drilling longholes with percussion drills instead of diamond drills. When 2-in. tungsten carbide insert bits became available in 1948, test work began by using the same ring patterns that had become standard practice with diamond drill blastholes. By the end of 1948, holes up to 40 ft in length were drilled without difficulty. Improved drilling technique and better water swivel design enabled holes up to 70 ft in length to be drilled successfully early in 1949, thereby indicating that the diamond drill would be eliminated entirely for ore breaking except in very special cases. This became an assured fact a few months later, when percussion drills took over the job at about 25 pct of the former cost.

Since percussion drill longholes began to replace diamond drill blastholes in 1948, several new ideas have been advanced for development work and miscellaneous drilling. New development schemes include driving short drifts or crosscuts and raises, with the latter having the widest use to date. For instance, during 1952, 492 ft of untimbered raises were driven by longholes at approximately 81.7 pct of the cost per foot for similar raises driven by conventional means during the same period. During the first 9 months of 1953, the cost for 259 ft of slot raises driven by longholes averaged only 56.5 pct of the cost for similar raises driven by conventional methods. Since experienced raise miners are scarce nowadays, this application for longholes gains in importance.

In addition to short crosscuts of normal cross-section up to about 35 ft in length, several openings much smaller in diameter have been driven by longholes with singular success. One example was a 52-ft crosscut driven with seven 2½-in. holes spaced to give an opening 36x36 in. This crosscut, which was driven at a −2° slope, was needed to provide access for an 8-in. stope filling pipe line. The ground was removed by a series of seven blasts. Another typical example of the possible use of longholes for special work was a 20-ft drainage hole driven from No. 2 sump into a waste pocket. Four 2-in. holes in the form of a square and spaced 8 in. from a center hole, 2½ in. diam, were drilled at a −21° angle and resulted in an opening about 18 in. diam. Blasting was done slowly by shooting short sections of single holes at a time because of the nearness of other installations.

One of the most recent applications of percussion drill longholes is for drain holes in stope filling programs. Wherever possible, 2½-in. holes are used because of their greater capacity. Lengths up to 67 ft of 2½-in. hole have been drilled without difficulty. The trend toward the increased use of percussion drill longholes for development and miscellaneous purposes is clearly shown by the following comparison of total work done to date by the two drilling systems:

	Diamond Drill Blastholes		Percussion Drill Longholes	
	Ft	Pct	Ft	Pct
Ore Breaking	698,145	96.9	323,423	88.1
Development	15,090	2.1	34,521	9.4
Miscellaneous	6,956	1.0	9,031	2.5
Totals	720,191	100.0	366,975	100.0

Research is being carried on constantly to improve shop practice and underground performance. Tangible results of such efforts are clearly shown by the following tabulation that includes all longhole drilling done to date with 2-in. and 2½-in. tungsten carbide insert bits.

Longhole Bit Data

Year	Ft Drilled	Bits Used	Average Ft per Bit	Cumulative Ft per Bit
1948	22,077	297	74.3	74.3
1949	80,746	530	152.4	124.3
1950	61,215	440	139.1	129.5
1951	58,895	420	140.7	132.2
1952	74,984	410	182.9	142.1
1953 (9 months)	60,595	319	190.0	148.4
Totals	358,512	2,416	148.4	

A full-time engineer is assigned to the longhole drilling program. His duties include laying out drilling patterns, preparation of sketches showing the location, inclination, and depth of each hole to be drilled, and the preparation of loading instructions showing the length of hole to be loaded and blasting delay to be used.

Each driller hands in a daily report showing the stope, ring number, number of holes drilled, serial number of bits used, feet drilled, and general remarks. The longhole engineer records this data on the drilling instruction sheets in the mine foreman's office and in his own permanent records. The research engineer uses the bit and footage data, as reported by the drillers, in his permanent records.

Longhole drilling is placed on bonus whenever practical at a rate of 20¢ per ft above days pay for

Records of Individual Drill Operators

Driller	Experience	Footage	Shifts	Average Ft per Shift	Average Best Month Ft per Shift
A	43 months	66,473	997	66.7	105.3
B	39 months	57,717	803	71.9	95.8
C	5 months	4,880	86	56.7	69.8
D	2 months	3,678	54	68.1	75.1
E	1 month	607	18	33.7	33.7

Drilling Data — 1938 to Date
Howe Sound Company — Chelan Div.

	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953
CONVENTIONAL STEEL	*	*	*													
Feet Drilled	426,165	656,210	890,858	339,061	8,166	14,253	2,514	25,696	2,247	—						
Sharpenings	323,391	497,959	676,019	257,294	5,068	8,351	1,907	13,788	5,828	642						
Feet per Bit	—	—	—	1.6	1.6	1.7	1.3	1.9	0.4							
DETACHABLE BITS																
Feet Drilled			151,896	843,318	686,671	231,792	1,732									
New Bits			No Record	93,785	86,270	38,700	—									
Bits Sharpened			67,175	372,947	281,288	105,100	—									
Uses per Bit			—	5.0	4.3	3.7	—									
Feet per Bit Use			—	1.8	1.9	1.6	—									
C & R BITS (COMPANY MADE)																
Feet Drilled					70,354											
Bits Made					11,722											
Bits Sharpened					42,069											
Uses per Bit					4.6											
Feet per Bit Use					1.3											
ONE-USE BITS																
Feet Drilled						373,249	517,173	169,030	226,847	630,504	424,062	166,016				
New Bits						223,700	287,450	90,202	141,726	347,390	216,156	25,950				
Feet per Bit						1.7	1.8	1.9	1.6	1.8	2.0	2.1				
New Rods						No Record	No Record	875	2,502	6,211	2,652	803				
Rods Reconditioned						No Record	No Record	7,007	10,036	15,268	8,585	2,611				
Feet per Rod Use						—	—	21.4	18.1	29.4	37.7	48.6				
TUNGSTEN-CARBIDE BITS—1½-IN.																(9 Months)
Feet Drilled												321,154	554,728	471,766	324,414	324,131
New Bits												2,176	3,371	3,153	1,741	1,300
Feet per Bit												147.6	164.6	149.6	186.3	249.3
New Rods												907	1,514	1,180	689	763
Rods Reconditioned												4,410	7,017	4,445	3,654	2,820
Feet per Rod Use												60.4	65.0	83.9	74.7	90.5
TUNGSTEN-CARBIDE BITS—1⅜-IN.																
Feet Drilled															10,834	49,568
New Bits															59	228
Feet per Bit															183.6	217.4
New Rods															36	216
Rods Reconditioned															—	80
Feet per Rod Use															301	167.5
	*	*	*													
TOTAL FOOTAGE DRILLED	426,165	656,210	1,042,754	1,182,379	765,191	619,294	521,419	194,726	229,094	630,504	424,062	487,170	554,728	471,766	335,248	373,699
STEEL SHOP CREW																
Average Shifts per Day	8.6	10.9	13.7	12.3	8.6	3.6	2.1	1.2	1.2	2.0	1.9	2.2	1.9	1.3	2.0	1.9

NOTE: * No record of exact footage drilled—Estimated from results in 1941. — Estimated from results in 1941 — Estimated from results in 1941

every foot drilled over a 50-ft average per bonus shift during a bonus week. Holes are measured and spotchecked by the longhole engineer when any chance of shortholing is suspected. Footage is based on the amount of usable hole. Lost holes do not count toward bonus; neither do holes drilled at an improper angle or in a wrong direction. Bonus time includes recovering broken rods and bits, moving and setting up in the same stope or level, and time spent in replacing equipment. Machine breakdown is considered company time.

As a comparison, the overall average attained by diamond drills on blastholes was about 28 ft per shift and the highest footage reported for any diamond driller was 50 ft in one shift.

At the present time, standard longhole drilling equipment includes the following:

1. Four-in. drifters with 36-in. change power feeds mounted on 54-in. aluminum sliding cone shells.
2. Adapters of 1¼-in. round carbon steel lugged to fit the machines.
3. Water swivels of local design, introducing sufficient volume of water at 75 to 80 psi to clean the cuttings from the holes.
4. Drill rods of 1⅛-in. round carbon steel in 36-in. and 72-in. lengths with type 2 couplings made locally. A 1¾-in. collar is forged on the lead steel a few inches above the threads as a preventative against squaring the holes.
5. Two-in. tungsten carbide insert bits are standard with 2½-in. bits being used for special work and testing purposes.

Recent test work has indicated that locally made water swivels will be replaced by a manufactured type with "O" type rubber seal rings. The new type is much lighter, produces considerably less water spray, cheaper in original costs, and should result in less maintenance cost.

One of the chief secrets in longhole drilling is to maintain water at high pressure and volume at the bit end to keep the cuttings washed clean from the hole. A larger waterhole in the drill steel would appear to be an improvement and further research along this line is intended.

Testing of alloy steel for longhole drilling is underway but no definite economy in the operation is apparent to date. Two advantages are: the steel is lighter and couplings loosen more easily when pulling rods. On the other hand, coupling cost per foot drilled will be about double that for locally made couplings and the original cost of alloy steel is higher. Before a definite conclusion can be drawn, alloy steel will have to drill much more footage to provide a fair basis of comparison.

The years 1940 and 1950 were chosen for comparison because normal operations were carried on then without interruption from strikes or shutdowns. In 1940, all ore breaking was done by powder blasts; all ore gathering by bulldoze chambers; and the possibilities of detachable bits for drilling and diamond drill blast holes for breaking ore were just being investigated. By 1950, powder blasting was completely eliminated; slushing was standard procedure for one gathering; drilling rock had passed through the cycle from conventional steel to tungsten carbide insert bits; and the diamond drills had been completely replaced by percussion drills for ore breaking by longholes.

Since the advent of push feed drills in this country a few years ago, several types of drills and steels were tried, but no combination could measure up to the equipment then in use until 1952 when test work began to show definite possibilities. Continued work with lightweight machines and alloy steels indicates that a successful combination of push feed drills, alloy steel, and tungsten carbide bits may be found, which will replace some or a substantial part of the equipment now considered standard for regular drifting and raising. Quite definitely, push feed drills have proven superior in undercutting and in tight places such as collaring off drifts or cross-cuts from service raises. Also, lightweight drills equipped with stoper legs are meeting with considerable favor by some raise miners. In view of the expanding use of lightweight drills, it is now apparent that the Holden mine may be again passing through another cycle in the science of drilling rock.

Longholing in a Large Canadian Underground Mine

AT one Canadian operation, 70 to 80-ft holes are being drilled successfully with sectional drill rods and tungsten carbide bits. Standard drill rod used is 1-in. hexagonal alloy with a modified reverse buttress thread and an upset bit attachment. At the machine, a special shank rod is used with a rubber "O" ring for the water needle. All rods are purchased and only repair of broken rods is attempted at the mine. The most common bit used is 2½-in. Carset, but many other types are being tested regularly.

However, it was reported that some difficulties have been encountered with peening of the machine hammer, because the special treatment given the shank rod produces high hardness. This is being overcome by reducing the hardness and the introduction of a new 1½-in. diam shank rod. The larger area presented to the hammer has virtually eliminated peening. With shank rods of all types drilling life is no problem. Over 250 ft is regular service for this fixture.

At present this operation is testing a new 4½-in. drifter for longhole drilling. The machine is mounted on a 4-ft aluminum shell with a sliding cone. All indications are that the larger machine will give better drilling speed and the hole diameter can be enlarged from the present 2½-in. standard. Investigations are proceeding steadily and interesting results are in the offing.

LITHIUM

Northeast Brazil Is Potential Source

Of the 61 dikes examined some yielded cassiterite, tantalite, and beryl; eight contained spodumene; and six carried amblygonite. Two mines stockpiled spodumene as a byproduct. Only zoned pegmatite dikes carried lithium minerals.

by W. B. Mather

GEOLOGICAL studies have revealed the occurrence of hundreds of pegmatite dikes in northeast Brazil, Fig. 1, in the three states of Rio Grande do Norte, Paraiba, and Ceara. Heretofore data have not been available on the possible production of lithium minerals from these areas, and in March, April, and May 1953 the author undertook a reconnaissance survey covering a cross-section of the pegmatites. Sixty-one pegmatites were examined.

The pegmatites of Rio Grande do Norte and Paraiba are located in an arid region (Seratao), and except in the most southerly portion there is a minimum of vegetation and overburden. The region is easily prospected and relatively accessible by jeep or truck. The pegmatites examined in Ceara are in an area of lush vegetation along the flanks of the Jaqueribe River valley. It is therefore more difficult to prospect, and the dirt roads, as a means of access, leave much to be desired. For all practical purposes rail transportation, except in Ceara, is not available.

The rocks of the area[1-4] are composed of Pre-Cambrian schist, gneiss, quartzite, and marbles. They have been intruded by granites, monzonites, and diorites and cut by quartz veins and pegmatites.

Pre-Cretaceous erosion reduced the area to a peneplain upon which Cretaceous or younger sandstones were deposited. Recent erosion has left only a few remnants of these younger rocks. In most of the Rio Grande do Norte-Paraiba area the pegmatites were more resistant to erosion than the enclosing schists and therefore stand out in relief. This is not true in the rolling country of Ceara, where the pegmatites lack topographic expression.

With regard to structure and lithology, the pegmatites of northeast Brazil are divided into two types, uniform and zoned. Of the 61 examined, 19 belong to the uniform and 42 to the zoned type. Uniform pegmatites are normally long, narrow, and tabular, with sharp contacts. They are composed of an intimate mixture of feldspar (microcline or orthoclase), mica (biotite, phlogopite, or muscovite), and quartz. The grain size[5] varies from fine at the contact to coarser in the interior. They are not considered a commercial source of pegmatite minerals, although efforts have been made to produce green beryl of gem variety. This type of dike is often abundant in schists and gneisses close to granite intrusives.

The productive dikes — lenticular, pod-shaped, or irregular in outline, with sharp contacts — are of the zoned variety. Zone contacts are gradational, except for those with the quartz core. Zones[6] are identified as follows, see also Fig. 3.

Border Zone: This outer zone, in contact with the country rock, is composed chiefly of fine-grained muscovite and biotite, with lesser quantities of fine-grained microline and quartz. It is the narrowest zone, usually measurable in inches.

Wall Zone: Lying between the border and intermediate zones, the wall zone is composed of medium-grained feldspar (often microcline), muscovite, and quartz. Usually it is the widest zone. Widths of 50 ft were noted.

Intermediate Zone: Lying between the wall zone and core, the intermediate zone is composed principally of coarse-grained microcline (occasionally with some orthoclase and albite). It may also carry minor amounts of coarse-grained quartz and fine to medium-grained mica. The width varies from less than 3 ft to more than 30 ft.

Core: The center of the dike is composed almost entirely of massive quartz, occasionally with minor amounts of fine-grained muscovite. The width reaches 30 ft.

Lithium and other minerals of potential economic value are found in the following zones:

Spodumene	Zone 3 and outer part of zone 4
Amblygonite	Zone 3 and inner part of zone 2
Cassiterite	Zones 2 and 1
Tantalite-columbite	Zones 2 and 3
Beryl	Zone 3 and outer part of zone 4. Occasionally in zone 2
Mica	Zones 2 and 1

Weathering of spodumene and amblygonite produced sharply contrasting results. Spodumene has weathered more rapidly and to greater depths than the other pegmatite minerals. Amblygonite is one of the minerals most resistant to weathering.

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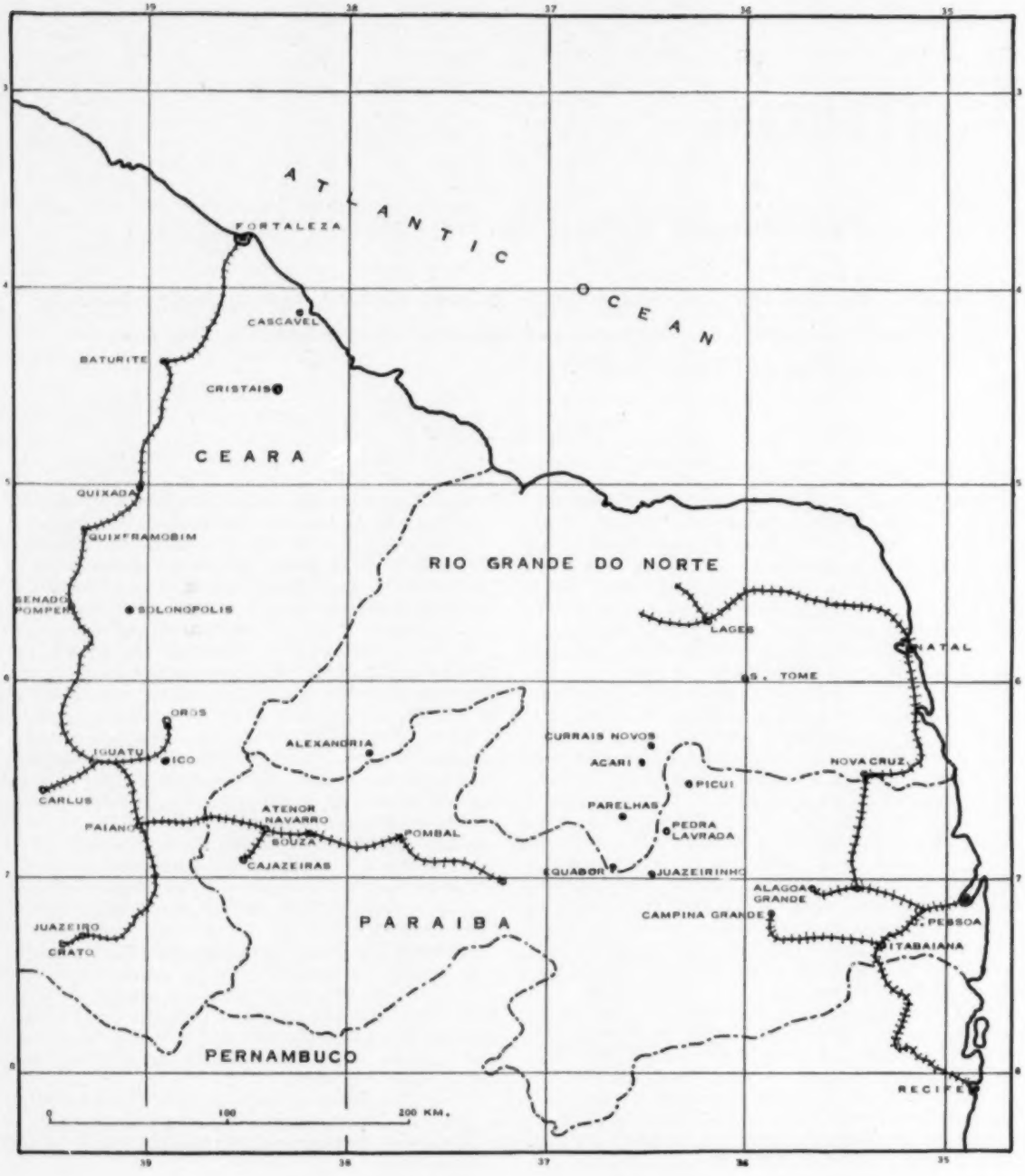

Fig. 1—Index map of northeastern Brazil.

The following minerals were also identified, usually in zone 2: pyrite, lepidolite, tourmaline (also zones 1 and 3), apatite, chalcopyrite, chalcocite, malachite, carnotite, ilmenite, magnetite and arrojadite (also zone 3). Additional minerals identified[7] in these pegmatites are: microlite, simpsonite, rare earth tantalates and niobates, monazite, pitchblende, garnet, metallic bismuth, zircon, lazulite, rhodonite, and molybdenite.

The principal lithium-bearing pegmatites were found in two general areas, Fig. 1. The first extends across the state line from Parelhas and Acari in Rio Grande do Norte on the west to Pedra Lavrada and Juazeirinho in Paraiba on the east. In this report these have been further subdivided geographically into deposits in Rio Grande do Norte and in Paraiba. The second is west and north of Solonopolis in the Cachoeira-Quixeramobim area of Ceara.

The third area, the Cascavel-Cristais district of North Ceara,[8] is known to contain lithium-bearing pegmatites (amblygonite). These were not examined because they have not been mined for several years and workings were reported caved and flooded.

Of the seven pegmatites examined in Paraiba, see Fig. 2, four contained lithium minerals. Two of these, Seridozinho and Pedras Pretas, are located in an

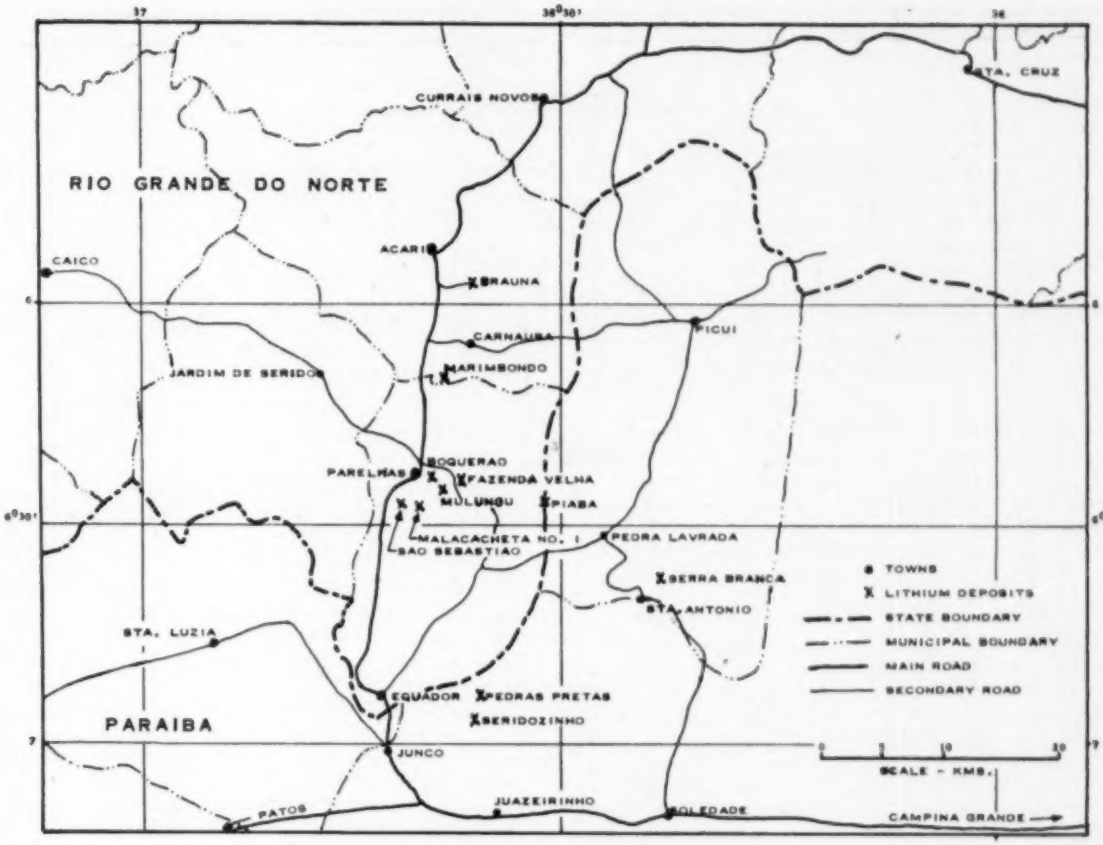

Fig. 2—Index map of lithium deposits in Rio Grande do Norte and Paraiba.

area covered by a mantle of topsoil. The other two are located in a rocky terrain practically devoid of vegetation and overburden.

Seridozinho: Fig. 4 is a sketch of the Seridozinho workings. The mine is located in the southern part of the area on the Borborema plateau, 6½ miles northwest of Juazerinho. One ton of hand-sorted tantalite-columbite and one ton of cassiterite were produced per month. Current beryl production figures were not available. Mining of spodumene was incidental to production of the other minerals. It is reported that total spodumene production to date has been 800 to 1000 tons. Several stockpiles, see Fig. 5, containing an estimated 300 to 400 tons were examined.

During World War II two open pits were brought into operation as a result of tantalite-columbite mining. The south pit, 600 ft long, averages 75 ft wide and 30 ft deep. The north pit is 250 ft long, 90 ft wide, and 80 ft deep. A test-pitted area, 125 ft long and 105 ft wide, averaging 15 ft deep, lies between the two pits. The exposed length of the dike, therefore, is nearly 1000 ft, the width varying from 60 to 105 ft. Present mining operations consist of hand-sinking gopher holes in the floor of the main pit. The maximum depth of the original open pits was 30 ft. The narrow gopher holes extended this to over 45 ft. The owner stated that the old test pits, now caved, indicated a northeast extension of the dike for an additional 500 ft.

The pegmatite has intruded a highly contorted mica schist. The general strike varies from N 40° E to N 60° E. The dip of the upper part of the east wall varies from 45° to 60° E. Present mining operations indicate that the west wall dips at approximately 45° W. At a depth of 35 ft below surface the dips of both walls are flattening, suggesting greater widths than revealed at the surface.

Spodumene occurs in zone 3 and the outer part of the quartz core. Weathering has destroyed most of the spodumene within 20 ft of surface. Spodumene crystals along the outer part of the quartz core are especially massive, often measuring 2 ft wide and 6 in. thick, with a length of more than 5 ft exposed. The walls of the gopher holes sunk in the floor of the main pits contain as high as 70 pct spodumene, 40 pct being common. Width of the spodumene zone varies from 30 ft (15 ft on each side of the core) to 60 ft. Although current erratic mining

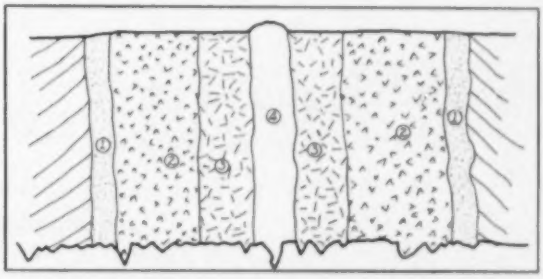

Fig. 3—A cross-section of zoned pegmatite. Circled numbers indicate the following zones: 1—a fine-grained contact; 2—normal pegmatite complex; 3—massive feldspar; and 4—the quartz core.

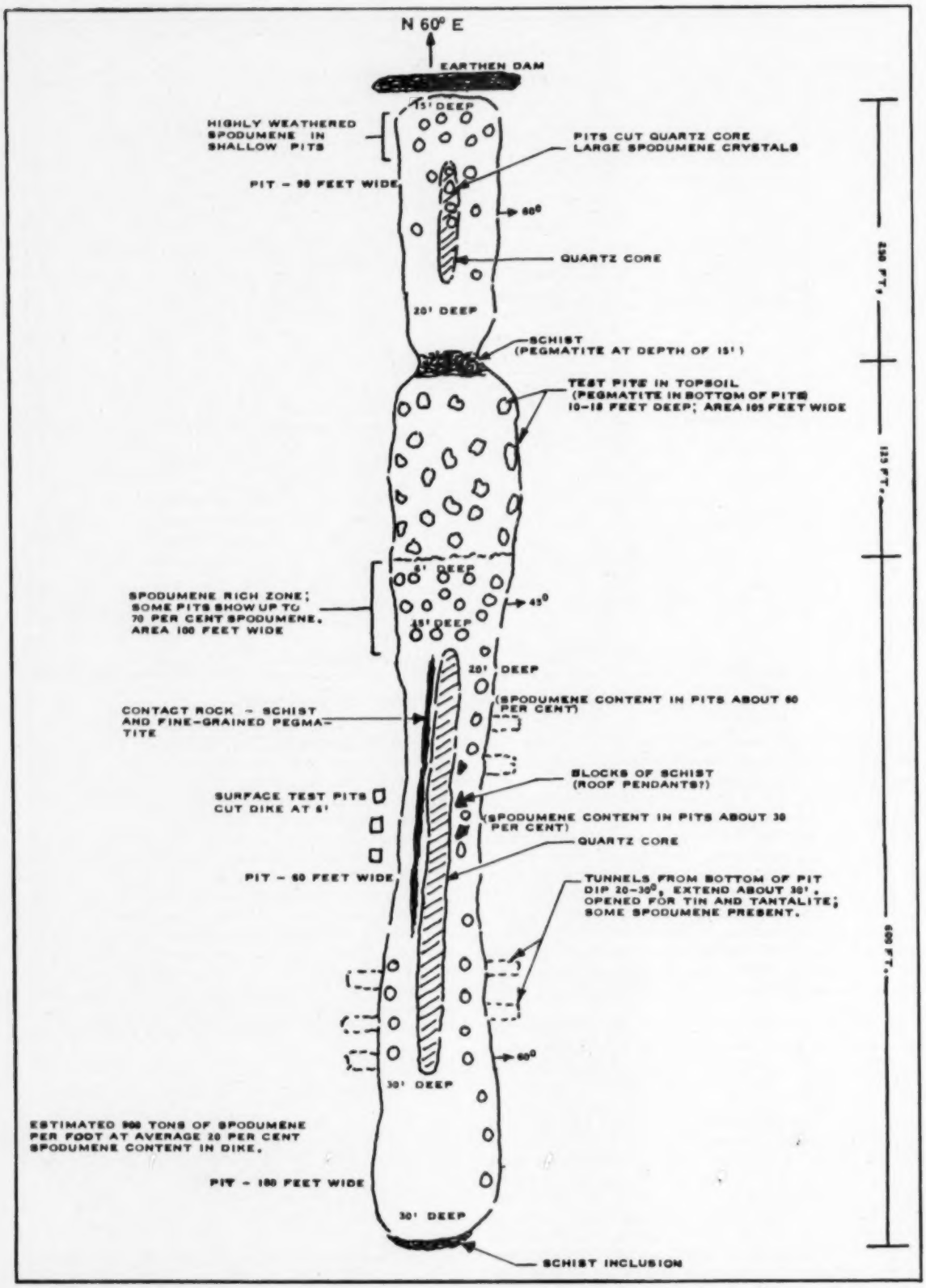
N 60° E
EARTHEN DAM
15' DEEP
HIGHLY WEATHERED SPODUMENE IN SHALLOW PITS
PITS CUT QUARTZ CORE LARGE SPODUMENE CRYSTALS
PIT – 90 FEET WIDE
60°
QUARTZ CORE
20' DEEP
SCHIST (PEGMATITE AT DEPTH OF 15')
TEST PITS IN TOPSOIL (PEGMATITE IN BOTTOM OF PITS 10–15 FEET DEEP; AREA 105 FEET WIDE
230 FT.
135 FT.
5' DEEP
SPODUMENE RICH ZONE; SOME PITS SHOW UP TO 70 PER CENT SPODUMENE. AREA 100 FEET WIDE
45°
45' DEEP
20' DEEP
(SPODUMENE CONTENT IN PITS ABOUT 60 PER CENT)
CONTACT ROCK – SCHIST AND FINE-GRAINED PEGMATITE
BLOCKS OF SCHIST (ROOF PENDANTS?)
SURFACE TEST PITS CUT DIKE AT 5'
(SPODUMENE CONTENT IN PITS ABOUT 30 PER CENT)
QUARTZ CORE
PIT – 60 FEET WIDE
TUNNELS FROM BOTTOM OF PIT DIP 20–30°, EXTEND ABOUT 30', OPENED FOR TIN AND TANTALITE; SOME SPODUMENE PRESENT.
600 FT.
60°
30' DEEP
ESTIMATED 900 TONS OF SPODUMENE PER FOOT AT AVERAGE 20 PER CENT SPODUMENE CONTENT IN DIKE.
PIT – 180 FEET WIDE
30' DEEP
SCHIST INCLUSION

Fig. 4—Sketch of the Seridozinho workings.

practice makes ore estimations hazardous, it is believed that the average spodumene content in zones 3 and 4 is in excess of 20 pct; therefore the mine could produce at least 900 tons of spodumene per foot of depth. The owner was asking 40 centavos per kilo ($8.00 per ton) for hand-sorted spodumene.*

* The mine was revisited by the author in June 1954. The owner stated that during the past few months she had sold 800 tons of spodumene concentrates to buyers from Campina Grande and Recife for 1.80 cruzeiros per kilo ($36.00 per ton at the mine). The mine is now closed because the owner is demanding 2.50 cruzeiros per kilo ($50.00 per ton at the mine).

The possibilities for production of spodumene, tantalite, cassiterite, and beryl from this pegmatite are attractive. The dike has adequate length and is widening with depth. Unmined roof pendants, observed at ground level, indicate that the present land surface may coincide with the upper portion of the dike. The vertical extent of the dike may therefore be considerable.

Pedras Pretas: This inactive mine, 3 miles northeast of Seridozinho mine and 9 miles northwest of the town of Juazerinho, was a cassiterite producer. A pegmatite 4 to 10 ft wide was mined by open pit along the strike for 300 ft to a maximum depth of 40 ft. The strike is N 45° E; the dip varies from vertical to 75° E. The wall rock is mica schist.

Subsequent mining efforts were located at the northeast end of the narrow cassiterite producer where a roughly circular pit was opened over a diameter of 200 ft to a maximum depth of 25 ft. The rock in the floor and walls of the pit is a mixture of blocks of country rock and zoned pegmatite. A small area of the massive quartz core is also exposed in the floor of the pit. Spodumene was found in the massive feldspar of zone 3, while spodumene casts were observed in the quartz core. Weathering has highly altered the exposed spodumene.

A third area, immediately to the northeast of the circular pit, has been investigated by a smaller excavation 60x50x25 ft. Identical spodumene-bearing material was found.

The latter two excavations suggest a total dike length of at least 300 ft. The spodumene content, based on present exposures, is lower than that of Seridozinho.

Piaba: The deposit is located 4 air miles, or 11 miles by road, northwest of Pedra Lavrada. At present beryl, tantalite-columbite and spodumene are being mined from an irregular-shaped open pit, 150x75x35 to 50 ft deep.

The pit is located in the southern part of a pod-shaped pegmatitic mass with the long axis striking north-south. The dike, 100 ft wide, crops out for 250 ft along the strike. Country rock is mica schist.

The pegmatite is erratically zoned with large spodumene pods occurring in the feldspar of zone 3 and also in the quartz core. The spodumene is often associated with fine-grained light green mica and rose quartz. Spodumene content of the south wall was estimated at 40 pct.

Stockpiles contained about 100 tons of hand-sorted spodumene, for which the owner was asking 40 centavos per kilo ($8.00 per ton). Current production was at the rate of 8 tons of hand-picked spodumene per week.

Serra Branca: This pegmatite[9-11] is located 12 miles, by road, southeast of Pedra Lavrada, or 14 air miles southeast of Piaba mine. During World War II it was mined for beryl and tantalite-columbite. According to the owner, beryl crystals as large as 50 tons have been mined. There has also been a minor production of cassiterite and amblygonite.

The pod-shaped pegmatite has been explored and mined by an open pit 300x100x50 ft deep. The long axis strikes northwest; the dip is vertical. The country rock is mica schist. Irregular-shaped masses of white to greenish amblygonite occur erratically in microcline and orthoclase of zones 3 and 2. Although individual amblygonite masses measure 2 ft in cross-section the overall percentage is low. Black tourmaline and arrojadite are conspicuous components of zone 2. Cassiterite was observed intergrown in masses of fine-grained greenish mica.

Conclusion: Seridozinho offers the most promising known lithium deposit in northeast Brazil. Pedras Pretas requires drilling to determine the extent of the spodumene zone. This particular area merits development, as it probably contains other spodumene deposits. Because of overburden, exploration for pegmatites can best be accomplished by geophysical methods. In the Piaba and Serra Branca areas many large unexplored pegmatites crop out. Since spodumene weathers to a depth of at least 20 ft, these pegmatites must be prospected by drilling or test pitting.

Deposits in the State of Rio Grande Do Norte

Of the 35 pegmatites examined in Rio Grande do Norte, see Fig. 3, seven contain lithium minerals. Ridges extending for several hundred feet above the surrounding valleys are the principal topographic features. Because of very low rainfall and lack of vegetation and topsoil, the area is easy to prospect.

Boquerao: The pegmatite[12] is located on a ridge top about 900 ft above and two miles east of the town of Parelhas. The deposit, now inactive, was mined during World War II as a tantalite-beryl producer. The owner stated that 300 tons of beryl and 25 tons of tantalite-columbite had been produced. Open pit mining has exposed the pegmatite for 600x100x35-ft maximum depth. The quartz core has been circumvented, leaving this large mass, 300x30 x25 ft high, standing along the central axis of the dike, see Fig. 6.

The pegmatite is vertical. It strikes N 60° W and intrudes a conglomerate that strikes N 80° W. The principal lithium mineral is spodumene. Some lepidolite and amblygonite were noted. The spodumene zone is 6 to 8 ft wide on the south side of the core and 3 to 10 ft wide on the north side. Spodumene crystals in the quartz core are very coarse. Weathering has removed part of the spodumene; its original presence is revealed by casts in massive quartz.

The spodumene content is difficult to estimate because the floor of the pit is partially concealed by an accumulation of debris. The owner stated that the spodumene content was about 10 pct.

Mulungu: This pegmatite has recently been opened as a beryl and tantalite-columbite producer. It is located 4½ miles southeast of Parelhas, along the side of a ridge at an elevation of about 600 ft above the surrounding country. The only means of access is on foot.

The strike is N 70° W and the dip vertical. It intrudes the same conglomerate as Boquerao. The dike has been exposed by a series of small open pits 15 to 25 ft deep along the strike for a distance of 400 ft. The width is unknown, but it is believed to be less than 40 ft.

Spodumene, encountered in the largest pit at the northwest end of the workings, occurs in

Fig. 5—Spodumene stockpiles at the Seridozinho mine.

massive quartz (zone 4) along a 20-ft face. The spodumene content was estimated at 5 to 10 pct. Similar occurrences were observed in the smaller pits to the southeast. Amblygonite intergrown with feldspar and white beryl was noted in one pit. The pegmatite was not sufficiently exposed to permit an estimate of available spodumene.

Fazenda Velha: This deposit,[13] located 6 miles east, southeast of Parelhas, was mined during World War II for beryl and tantalite. A production of 300 tons of beryl and 12 tons of tantalite-columbite was reported. It has been virtually inactive since then.

The pegmatite is vertical, striking northeast and intruding mica schist. It has been exposed along the strike by an ellipitical-shaped open pit 150x45x50 ft deep. A section of the quartz core has been left standing along the central axis of the dike.

Spodumene occurs over a width of 8 to 10 ft in zone 3, on each side of the quartz core, for a distance of 60 ft along the strike. The accumulation of debris on the floor of the pit prevented a detailed examination of the spodumene zone.

Malacacheta No. 1: This deposit is located 5.2 miles south of Parelhas. The pegmatite, which strikes N 70° E, has been exposed by five pits for 200 ft along the strike. The largest of these is 15 ft in diam and 60 ft deep. The wall rock is mica schist. Although zoning is not apparent, it is believed that the present operations are in zone 2. A small quantity of amblygonite was identified in the largest pit. Mica is the only mineral that has been produced.

Sao Sebastiao: This dike is identical with Malacacheta No. 1 and is also a mica producer. It is located 0.8 miles to the west of Malacacheta No. 1. The deposit is mined by two pits, 60x30x25 ft and 50x20x25 ft. A small quantity of amblygonite was identified.

Marimbondo: The mine, now inactive, was formerly worked for beryl, tantalite, and cassiterite. It is located 2½ miles S 60° W of Carnauba. The pegmatite is elliptical in outline and crops out on the flank of a ridge about 300 ft above the surrounding valley. It intrudes a mica schist. Open-pit mining was conducted to a depth of 45 ft, but the quartz core, 75x20 ft, was left standing. Several unexplored pegmatites were noted along the same ridge.

Biotite is especially abundant in zone 1, and there is an unusually large amount of muscovite in zones 2 and 3. The spodumene-bearing area, zone 3 and the outer part of the core, averages about 15 ft wide. The spodumene occurrences in the quartz core are massive crystals, 7 to 8 ft long; crystals weighing over 1000 lb are reported to have been mined. One face of the pit, 35x20 ft, contains more than 15 pct spodumene. A second face, 20x10 ft, carries an estimated 30 pct spodumene. The floor of the principal spodumene zone (zone 3) is partially covered by debris, preventing a more complete estimate of the spodumene content.

Brauna: This inactive mine is located 21 miles north of Parelhas on the Fazenda of Possidonio Avelino de Medeiros. It can be reached only on horseback or on foot. A shallow pit has exposed a zoned pegmatite at least 120 ft long and 45 ft wide. The country rock is mica schist. Beryl, tantalite-columbite, and amblygonite occur in small quantities in zone 3. The owner claims to have sold 10 tons of amblygonite for 40 centavos per kilo ($8.00 per ton). If so there must be richer amblygonite-bearing dikes than the Brauna somewhere on the fazenda.

Conclusion: The extent of the spodumene zone at Boquerao, Fazenda Velha, Mulungu, and Marimbondo must be determined by drilling before their productive capacity can be estimated.

Since five lithium deposits are known in the Parelhas district, it is reasonable to expect other occurrences among the many large unexplored pegmatites in the same district.

The most promising prospecting district, however, is believed to be in the vicinity of Carnauba, especially in the area represented by the Marimbondo pegmatite. Many larger unexplored pegmatites were observed in this vicinity. It is highly improbable that all the lithium was concentrated in the one deposit (Marimbondo).

Deposits in the State of Ceara

Fifteen pegmatites were examined in Ceara. Four contained lithium minerals. Johnston has described[18] six other amblygonite-bearing pegmatites in the Quixeramobim-Cachoeira area and four in the Cascavel-Cristais area. The district is one of deeper topsoil, and prospecting for pegmatites is therefore more difficult than in most of neighboring Rio Grande do Norte and Paraiba.

Soledade No. 2: This mine is located 4.5 miles northwest of Solonopolis. It is a beryl-tantalite producer. Minor amounts of spodumene and amblygonite have also been mined. The zoned dike is over 300 ft long; the width varies from 20 ft at the southwest to 60 ft at the northeast. It strikes N 75° E, discordantly to the enclosing micaceous quartzite. The dip is vertical.

A lenticular-shaped open pit has exposed the pegmatite for 300 ft along the strike and to a depth of 25 ft. The spodumene zone is exposed for 300 ft along the strike and ranges in width from 1.5 to 30 ft. Spodumene crystals are smaller in the coarse-grained feldspar of zone 3 and larger in the outer part of the quartz core. It has been partially weathered to a depth of at least 25 ft. The spodumene content is about 8 to 10 pct. Amblygonite occurs in zones 3 and 2, southwest of the main quartz core outcrop. Beryl and tantalite occur further to the southwest in zones 2 and 3.

Soledade No. 1: This deposit is located one mile south and east of Soledade, No. 2. A narrow east-west trench in topsoil (maximum width of 20 ft) has partially exposed a narrow pegmatite for 100 ft along the strike. The latter intrudes micaceous quartzite at a small angle. Isolated masses of amblygonite were identified. Small quantities of beryl and tantalite have been mined.

Soledade No. 4: This dike is located about 1.5 miles north of Soledade No. 2. A pit 200x20x5 ft has exposed a vertical pegmatite striking N 80° E, discordant to the micaceous quartzite country rock. It had been mined for beryl. Amblygonite, associated with fine-grained greenish mica, was observed in massive feldspar in the east part of the pit. The quartz core was not exposed.

Auriverde: This mine is located 12 miles north of the town of Solonopolis. The long axis of the pit, and presumably of the pegmatite, strikes N 60° W. The country rock is mica schist. The dike is exposed in an open pit 200x40x40 ft deep. Currently it is mined for tantalite and beryl by sinking gopher holes in the floor of the main open pit. A small quantity of amblygonite is produced. A few spodumene and small blue apatite crystals were noted.

Conclusion: Of the four pegmatites examined on the Soledade property, three carried lithium minerals. One of these, Soledade No. 2, by employing modern mining and beneficiation practice, could probably become a producer. The lithium content is too low and the distribution erratic for economic development in the other three lithium-bearing pegmatites. Johnston's description of other amblygonite-bearing dikes in Quixeramobim-Cachoeira and Cascavel-Cristais areas does not offer much encouragement for lithium production from the pegmatites of these areas.

Mining is carried on by primitive hand methods. Dynamite or black powder is used sparingly in a few instances in the state of Ceara.

The pegmatite minerals are concentrated by hand-picking *in situ* and carried from the pits in baskets on the backs or heads of the garimparoes (miners). The tin and tantalite concentrates are stockpiled in adobe or thatched sheds. In a few cases, lithium minerals are stockpiled beside the open pits. On the average, garimparoes receive 25 cruzeiros per day ($0.50 at present rate of exchange). The cost of trucking spodumene 250 km is estimated at 350 to 450 cruzeiros per ton ($7.00 to $9.00 at present rate of exchange).

Spodumene and amblygonite concentrates at the mine were offered at 40 centavos per kilo, or 400 cruzeiros per ton ($8.00 at current rate of exchange). Concentrates could, therefore, be deposited at the ports of Natal or Recife for about 750 to 850 cruzeiros or $15.00 to $17.00 per ton, depending on the existing rate of exchange.

The Brazilian government export quota on lithium concentrates for 1953 was 3000 tons. Fortunately the exportation of lithium minerals is under the jurisdiction of the Commission for Exportation of Strategic Materials, rather than the usual government agency. At present there is no quota on the exportation of lithium salts. To overcome the export restrictions on ore, it would appear logical to convert the concentrates to lithium salts in Brazil.

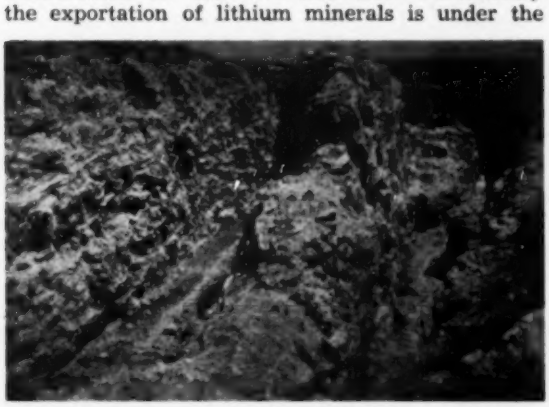

Fig. 6—Quartz core isolated by mining of massive feldspar. Unmined zone 2 (Boquerao) adjoins feldspar.

General Conclusions

The pegmatites of northeast Brazil, particularly in the states of Rio Grande do Norte and Paraiba, offer possibilities as sources of lithium ore. Lithium minerals were found only in zoned pegmatites.

As sources of lithium ore, Brazilian spodumene deposits are considered preferable to amblygonite deposits. Spodumene crystals occur in greater concentrations; they are more uniform in distribution; and they are more easily separated from the enclosing quartz, feldspar, or mica. Spodumene weathers more rapidly than the other pegmatite minerals, whereas amblygonite is one of the most resistant to weathering. Spodumene is usually weathered to a depth of at least 20 ft.

In certain instances beryl, cassiterite, and tantalite-columbite may be produced with spodumene.

Of the 61 pegmatites examined, Seridozinho and possibly Piaba and Soledade No. 2 are potential spodumene mines. Pedras Pretas, Boquerao, Fazenda Velha, Mulungu, and Marimbondo require drilling to determine the extent of their spodumene zones. Unexplored pegmatites in the vicinity of Parelhas and Carnauba in Rio Grande do Norte, Piaba, and Serra Branca in Paraiba merit exploration. Because of heavier overburden, geophysical prospecting methods should be employed in the Seridozinho and Soledade areas.

The choice of beneficiation methods will be limited by the extreme scarcity of water in Rio Grande do Norte and Paraiba.

To avoid export restrictions, some consideration should be given to the conversion, in Brazil, of lithium concentrates to lithium salts.

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Origin of Uranium Deposits

A Progress Report

by Donald L. Everhart

The search for new deposits raises two important questions: Where did the metallic ions that formed the orebodies come from? What processes and geologic factors were involved in ore replacement? A review of the wide geological variety of recent uranium discoveries tells how these questions are being answered.

SOONER or later intelligent exploration for uranium leads to these questions: Where did the metallic ions that formed the orebodies come from? What processes and geologic factors were involved in ore replacement? These matters, of course, make a big difference in how best to look for orebodies.

Before these questions are discussed it might be well to point out other factors bearing on the subject. The whole business of uranium exploration is only a little over ten years old, participation by the public is only about six years old, and real interest and activity by more than a few large mining companies has arisen only in the past two or three years. Throughout this short period, uranium exploration has been affected by the unique influences of necessary security measures and by division of the overall job into individual projects by a large number of specialists in diverse fields. This has meant that a normal interchange of information on the nature of uranium deposits has really only just begun. Compared to the vast amount of published studies on iron, copper, lead, zinc, and gold deposits over the past 50 to 75 years, current knowledge of uranium deposits is in its infancy and much of the pertinent information is still scattered about in a number of unpublished sources. The volume of reports on all phases of uranium exploration is now beginning to mount at a remarkable rate, and geologists with widely varying specialized backgrounds in uranium geology are engaging in spirited debates over the origin of uranium and the relative importance of geologic controls of various deposits.

One of the most interesting features of known uranium deposits of the world is the wide variation, see Table I, in character and geologic environment. It should be noted that many types became prominent during 1953.

The davidite-bearing veins of **Radium Hill, South Australia,** are almost unique, although the same mineral occurs in a different kind of deposit in Mozambique. Recent studies indicate that brannerite disseminated in the granite near **Crocker's Well, South Australia,** may soon constitute uranium ore. Basalt has been added to the list of favorable host rocks in the **Northern Territory of Australia.** Basalt is also the host of the pitchblende veins of the Martin Lake deposit, **Beaverlodge district, Saskatchewan.** The truly remarkable rich and extensive Steen deposit near **Moab, Utah,** is of the uraninite-vanadium oxide type. Secondary hydrous uranium arsenates and phosphates constitute the uranium minerals in the disseminated deposits of the **Wind River Basin, Wyo.,** a new district discovered in the summer of 1953. Uranium minerals in shales adjacent to fractures were newly reported in New Mexico and several other parts of the world during the year. The well-known important uraninite dissemination in the Rand conglomerates of South Africa has a counterpart, as discovered in the summer of 1953, in the Mississagi quartzite and conglomerate of the **Blind River district, Ontario.** Gunnar deposit of the **Lake Athabaska district, Saskatchewan,** consists of uraninite in both granite and sedimentary gneiss beneath a granite cap, and large new orebody of the Eldorado Co. in the same general area follows a preferred stratigraphic horizon in schists.

Uranium is, generally speaking, a very soluble and ubiquitous element. It occurs in at least two valency states and for this reason is not easily tied down in natural solutions. As Gruner[1] has pointed out, it is probable that uranium starts in the hexavalent state in nearly all solutions instrumental in its transfer. It is believed that under oxidizing conditions the uranium moves in solution as the uranyl ion, UO^{++}. In solutions ranging in pH from 1 to 5, the uranyl ion is most commonly in association with

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Table I. Classification of Uranium Deposits by Host Rock

HOST ROCKS		FORM OF DEPOSIT	DESCRIPTION OF URANIUM DEPOSITS
IGNEOUS ROCKS	INTRUSIVES	VEIN	URANINITE IN SILICEOUS-PYRITE-GALENA VEINS URANINITE IN NICKEL-COBALT-COPPER-SILVER VEINS *DAVIDITE IN SILICEOUS TITANIUM-RICH VEINS
		PEGMATITE	URANIFEROUS PEGMATITE
		DISSEMINATED	*BRANNERITE IN GRANITE
	EXTRUSIVES	VEIN	*URANINITE IN VEINS CUTTING BASALT URANINITE IN VEINS CUTTING ANDESITE URANINITE IN VEINS CUTTING RHYOLITE
		DISSEMINATED	URANIUM PHOSPHATES IN EXTRUSIVE ROCKS
SEDIMENTARY ROCKS	CLASTIC SEDIMENTS	DISSEMINATED IN FLUVIAL SANDSTONES AND CONGLOMERATES	*URANINITE-VANOXITE DEPOSITS COPPER-URANIUM DEPOSITS URANIFEROUS ASPHALTITE DEPOSITS CARNOTITE DEPOSITS *DEPOSITS OF "SECONDARY" HYDROUS URANIUM OXIDES, PHOSPHATES, ARSENATES, ETC.
		DISSEMINATED IN SHALES	*URANIUM MINERALS IN SHALES ADJACENT TO FRACTURES AND SHEARS URANIFEROUS BLACK SHALES
		PLACERS AND BEACH SANDS	URANIFEROUS PLACERS AND BEACH SANDS
	CHEMICAL-ORGANIC SEDIMENTS	DISSEMINATED IN CALCAREOUS SEDIMENTS	URANIUM MINERALS IN LIMESTONE, ADJACENT TO FRACTURES URANIFEROUS PHOSPHATIC DEPOSITS
		LIGNITE BEDS	URANIFEROUS LIGNITE DEPOSITS
METAMORPHIC ROCKS	METAMORPHOSED SEDIMENTS	VEIN	IN SCHISTS AND PARAGNEISS
		DISSEMINATED	*IN QUARTZITE AND METACONGLOMERATE *IN SCHISTS AND PARAGNEISS
	METAMORPHOSED IGNEOUS ROCKS	VEIN	IN AMPHIBOLITES

*SIGNIFICANT DEVELOPMENTS IN 1953

Table II. Tentative Classification of Uranium Deposits by Origin

	MAGMATIC ORIGIN	HYDROTHERMAL ORIGIN	ULTIMATE ORIGIN OBSCURED, AFFECTED BY GROUNDWATER REDISTRIBUTION	POSSIBLE GROUNDWATER FLUSHING FROM VOLCANICS	SEDIMENTARY ORIGIN	BIOGENIC ORIGIN
DEPOSITS IN IGNEOUS ROCKS	BRANNERITE IN GRANITE	PITCHBLENDE IN VEINS CUTTING FELSIC INTRUSIVES				
	URANIFEROUS PEGMATITES	URANINITE IN VEINS CUTTING EXTRUSIVE ROCKS				
		URANIUM PHOSPHATES IN EXTRUSIVE ROCKS				
DEPOSITS IN METAMORPHIC ROCKS		PITCHBLENDE OR DAVIDITE IN VEINS CUTTING METASEDIMENTS OR AMPHIBOLITES				
		(*)	URANINITE DISSEMINATED IN METASEDIMENTS		(?)	
DEPOSITS IN SEDIMENTARY ROCKS		PITCHBLENDE OR THUCOLITE IN VEINS CUTTING SEDIMENTS				
		(*)	COPPER-URANIUM DEPOSITS		(?)	
		URANIUM MINERALS IN LIMESTONE, ADJACENT TO FRACTURES (?)				
			? URANINITE-VANOXITE DEPOSITS ?			
			? CARNOTITE DEPOSITS ?			
			"SECONDARY" HYDROUS URANIUM OXIDES IN SEDIMENTARY BASINS ?			
			URANIFEROUS ASPHALT DEPOSITS			
				URANIFEROUS LIGNITE DEPOSITS		
					URANIFEROUS BLACK SHALES (?)	
					URANIFEROUS PHOSPHATIC DEPOSITS	
					URANIUM MINERALS IN PLACERS AND BEACH SANDS	

(*) more likely origin
(?) less likely origin

$SO_4^=$, as far as most natural acidic solutions are concerned. Furthermore this solubility is effective down to room temperatures. It is also a well-established fact that several kinds of basic carbonate solutions, with a pH of 8.5 upward, hold uranium as complexed ions, at temperatures mostly from about 150°C upward. Thus only solutions that are nearly neutral, with pH from 5 to 8.5, usually fail to hold uranium in solution. Actually there are very few data available on the solubility of uranium compounds in various natural solvents, and much of the data that are available are in the confidential files of individual researchers. Much more printed information is expected in the next few years.

Although uranium in general is a comparatively soluble element, there are a number of effective precipitants. One of the most spectacular of these is carbonaceous matter, which acts in at least two ways: 1—it creates reducing conditions, during decomposition, with the production of H_2S, thereby radically changing the pH; and 2—it possesses powerful capacity to adsorb uranium from many kinds of solutions. High base-exchange clays also have a high affinity for uranium. In areas where uraniferous solutions have a pH of 5 or less any kind of carbonate acts as a precipitating agent. In the special case of certain pitchblende vein deposits, the botryoidal masses are commonly considered to represent the coagulation of a colloid. This largely depends on the presence of a suitable electrolyte. Thus when uraniferous colloids invade any new environment that produces charges opposite to those on particles in the colloid, neutralization, destruction of the dispersive property of the colloid, and deposition ensue. Emmons[3] also suggests transport of uranium as a halide, particularly in igneous rocks, with precipitation caused by decreasing pressure.

Within the past year the U. S. Geological Survey[4] has started a project to appraise the relative horizontal and vertical transmissivity of all the exposed sedimentary rocks of the Colorado Plateau. By use of water consumption data from four representative drilling projects, the Survey recently has evaluated the effect of fracture systems on the transmissivity of the Salt Wash member of the Morrison formation. Preliminary results show quantitatively a correlation between highly fractured, that is, highly transmissive areas and known ore deposits.

In the vein types of deposits, the hydrothermal alteration work of Kerr[4] and his associates in the Marysvale district, Utah, and that of Wright[5] in the Boulder batholith, Mont., have indicated the power of uraniferous hydrothermal solutions, in places, to soak several tens or even hundreds of feet into the granitic wall rock of the veins. This is reflected by an orderly zonal arrangement of mica and clay minerals, and parallels in a general way the observations on hydrothermal effects in the Tintic district, Utah, by Lovering[6] and in the Butte district by Sales and Meyer.[7] The same sort of evidence has been observed in Portugal.

In intrusive igneous rocks, as Brown[8] has pointed out, uranium has an ionic radius and charge which prevents it from fitting comfortably into the lattices of any of the common major granitic minerals, with the possible exception of biotite, but it can fit fairly well into the lattices of certain accessory minerals, notably zircon, sphene, pyrochlore, allanite, and apatite. Therefore, uranium appears to be generally localized in igneous rocks in those minerals which make up only a small fraction of the total weight of the rock. In studies of the distribution of uranium in granites, it has been noted that substantial fractions are not localized in the crystal lattices at all but appear to exist interstitially. These fractions are so loosely bound to the minerals that complete removal can be obtained by leaching the pulverized rock with dilute acids.

One more aspect of the geochemistry of uranium is pertinent to the problem of origin. Considering Mason's geochemical cycle, it is obvious from the classification of known uranium deposits, Table II, that uranium shows up in virtually every part of the cycle. Presumably because of its high solubility over a wide range in pH, temperature, and pressure, it can survive many of the geologic processes. Likewise, because of the variety of precipitants of uranium, many geologic environments in the cycle are favorable for precipitation and concentration.

Origin of Uranium Deposits

Putting together the widely varying geologic character of known deposits of uranium and some of these geochemical properties, it is possible to speculate to some extent on the origin of the uranium ions. From the standpoint of origin, see Table II, it may be concluded that the uranium present in accessory minerals of a granite or a pegmatite was formed during crystallization of the magma. This idea is commensurate with the principles of Bowen and other accepted ideas of magma cooling. Elsewhere in the geochemical cycle, it is almost equally clear that uranium held in organic compounds in such shales as the Chattanooga, which is more or less consistent in grade and character over hundreds of square miles, was laid down by the established processes of marine sedimentation. Uranium in the phosphate beds of Florida is also apparently part of the marine sedimentary rock itself, although in both the shales and phosphates redistribution in varying degree has undoubtedly taken place. The sedimentary nature of such minerals as detrital euxenite or fergusonite in placers is clear-cut.

Almost as easy to prove is the hydrothermal origin of typical uranium-bearing veins in various types of bedrock. The close association of pitchblende with Bastin's[9] nickel-cobalt-silver type of mesothermal vein deposits has been commonly observed. Many of the other uraniferous veins are of the relatively low-temperature silica-pyrite-chalcopyrite-galena type so common in hydrothermally formed mineral districts. In both types of deposits pitchblende occupies a variable paragenetic position, but its close genetic association to other hydrothermal minerals is well established.

The greatest doubts as to the origin of uranium deposits concern the disseminated deposits in sedimentary rocks. Foremost among these, of course, are the bedded deposits in the Colorado Plateau.

Most of the Colorado Plateau deposits are closely associated with certain sedimentary features. Ore lies essentially parallel to the bedding, and most of the deposits occur in the thicker parts and commonly near the base of sandstone lenses, many of which represent old scours or channelways; the trend of the long direction of the deposits and the trend of the ore rolls in the sandstone are roughly parallel to the trend of the fossil logs in the sandstone and to the general dip of the crossbedding. These relations suggest that primary structures in the sediments were instrumental in localizing most of the ore deposits. However, within the past year

or two it has become increasingly evident, as pointed out by Rasor,[10] that below the zone of oxidation much of the ore consists chiefly of oxides—uraninite and low-valent oxides of vanadium—and varying quantities of sulphides such as pyrite, bornite, galena, and chalcopyrite. In some ores a hard variety of uraninite previously reported only from hydrothermal vein deposits has been found. Studies by Stieff and Stern[11] of lead-uranium ratios in ores from the Colorado Plateau indicate that regardless of where they occur all the ores are about the same age and are no older than late Cretaceous. In several areas field relations strongly suggest that the deposits may be genetically related to faults, fractures, or salt dome structures. Two main hypotheses are generally advanced to explain the origin of the Colorado Plateau ores. One is that the ores are penesyngenetic and were formed soon after the enclosing rocks were deposited. Subsequently ground water may have dissolved and reprecipitated the ore, but the original uranium is said to have been already present in the host rocks. This hypothesis, of course, provides a reasonable explanation for the relation of ores to sedimentary features, but it still leaves unanswered the discrepancy between the age of the uranium and the age of the enclosing rock (if these ages are valid) and the fact that uranium occurrences are known in at least 18 separate stratigraphic units. A second hypothesis alleges that the deposits are essentially telethermal, somewhat similar in origin to the Mississippi valley lead-zinc ores. It is believed that the ore-bearing solutions originated at depth from an igneous source and ascended along fractures. After these solutions mingled to a great degree with circulating ground waters they must have cooled so that they were no longer strictly *hydrothermal*. The minerals were precipitated in favorable beds and sedimentary traps as much as several miles from the feeder structures.

The difficulties with this second theory are mainly location of the hypothetical igneous source and proof of the connection between major fractures and faults and the ore deposits. It has also been pointed out, particularly by Gruner,[12] that there is meager evidence for solutions having passed through much of the barren rock that necessarily would have been in the path of ore-bearing solutions on the way from feeder conduits to their final deposition sites. Another possible objection is that the very wide horizontal distribution of orebodies in the Colorado Plateau is considered by some to place a strain on entirely hydrothermal sources.

In metamorphosed and granitized sediments, as at the Gunnar gold property or the new Verna deposits in the Beaverlodge district, Saskatchewan disseminated uraninite also follows the bedding and other sedimentary features, but it is near major faults along which many hydrothermal vein deposits occur elsewhere in the district.

Denson, Bachman, and Zeller[13] have added another concept in suggesting that in the case of lignites overlain by even slightly uraniferous volcanics, the downward flushing of ground water through the volcanics may have picked up uranium in solution, which precipitated or adsorbed below by the carbonaceous matter. A similar hypothesis has been advanced by Bain[14] in explaining the uranium deposits in the Todilto limestone of the Grants district in New Mexico. Here ground water flushing of overlying uraniferous sandstone and precipitation by the carbonate rock below is envisioned. These ideas encounter debate in explaining the localization of the deposits, however, and fluorite, which is almost universally associated with the uranium in the Todilto limestone, must be explained this way, especially since fluorite veins in underlying pre-Cambrian rocks are parallel to the elongation of the uranium orebodies.

Nearly all the disseminated deposits in sedimentary rocks appear to have been greatly affected or redistributed to an unknown extent by the action of slightly acidic or slightly alkaline ground water. This is the real source of the dilemma. Since this reworking appears to have been so widespread and pervasive, it may be a long time before ultimate origin is proved in many cases. A few deep drillholes on suspected feeder structures in the Colorado Plateau might answer many questions, and the Atomic Energy Commission is considering plans for such testing. In the meantime, all geologic factors must be considered in relation to uranium deposits of all types. Uranium, after all, is not greatly different in its geochemical behavior from many other metals except that its high solubility causes ore controls to be extremely subtle.

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Underground Electrocarbonization of Coal And Related Hydrocarbons

by T. C. Cheasley,
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Electrocarbonization of coal will produce cheap fuel for electric power plants. The complete electrification of industry and domestic power consumption of gas generated as fuel *in situ* is a worthwhile goal for the coal industry. Production of synthetic oils, gasoline, and coal chemicals from coal gas will create additional new markets for the coal industry.

RANKING high in the nation's wealth of natural resources, readily available liquid and gaseous hydrocarbons are nevertheless falling steadily in supply, while industrial requirements for hydrocarbon compounds are greater today than during the peak period of World War II.

Theoretically, several processes will increase the future supply of liquid and gaseous fuels, but the practical application of these methods depends on two controlling factors: 1—that enough carbon-bearing material be available to warrant industrial exploitation, and 2—that the given process be physically, chemically, and economically applicable. With regard to the first factor, the Western Hemisphere is fortunately well supplied, see Table I.

Table I not only shows the extensive occurrence of many fuel sources, but also the wide discrepancy among quantities of fuel substances in various materials. Great quantities of potentially available fuel have not been recovered. Many coal seams and other hydrocarbon-bearing deposits are so situated that production is uneconomical by present-day mining or oilwell pumping methods, and even in many exploitable deposits where the most efficient production methods are used a large proportion of material is never recovered. Industrial production of hydrocarbon liquids and gases must be better balanced, and processes must be developed which will convert coals, oil sand, and oil shales into fabricated commodities.

Among the techniques employed by scientists and engineers to secure fuel masses not economically available at present are several processes of *underground gasification*. These are all concerned with converting raw materials into gaseous products by thermal treatment of source substances while they are still in the ground and therefore require that a subsurface heat (fire) zone be induced to affect pervasively the buried raw fuel deposit. This is possible only where sufficiently high temperature exists and where the fuel material is satisfactorily opened or channelized. Also, to compete successfully with common mining or oilfield practices, a given method must be controllable and must not involve greater operational expense than regular methods. Preferably, it should be less expensive.

Since the close of World War II, England has continued field studies of underground gasification methods. Experiments have also been conducted in Sweden, Estonia, France, Belgium, Italy, and Germany. The U. S. Government has sponsored field studies at Gorgas, Ala., and because gasification *in situ* is vitally important to establishment of the nation's fuel resources, the mining engineering department at the Missouri School of Mines has been actively interested in developing the process of underground electrocarbonization. Research was conceived by Erich Sarapuu, and preliminary experiments in treating bituminous coal were begun at the school in September 1947. The work consisted of laboratory experimentation until June 1948, at which time, through a cooperative agreement with the Sinclair Coal Co. of Missouri, pilot plant studies were instituted at the Tiger mine of the Hume-Sinclair Coal Co. near Hume, Mo., to test the encouraging laboratory findings. This comprehensive field program was pursued continuously until the beginning of 1952.[8-10]

The broad term *underground electrocarbonization* describes a unique gasification process that releases by electricity the desired economic constituents from a raw carbon-bearing material, converting the substance of such deposits into deliverable form and greatly reducing the cost-of-mining factor. Underground electrocarbonization is not subject to the major limitations of many other underground gasifi-

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cation procedures. That is, the digging of underground drifts is not necessary, and control of the process can be closely maintained throughout the operation. Access to the raw fuel *in situ* is attained by means of vertical boreholes which may be placed several hundred feet apart. Electric current is transferred to the fuel medium by pipeline electrodes inserted in these holes. The pipes serve also as conduits through which the liquid or gaseous materials generated can be conveyed to the surface.

The General Process of Underground Electrocarbonization

In the case of coal and oil shale, valuable materials may be derived from both fixed carbon and volatile matter. Oil sands can be expected to yield commercially only liquid hydrocarbon compounds. Because of these broad differences in the natural modes of occurrence of various sources of mineral fuels, any particular application of the general procedure of underground electrocarbonization will have peculiar special characteristics or phases. These phases, which may exist singly or in combination during an operation of the process, are as follows:

Electrolinking: As noted previously, it is necessary that linkages or channels be induced within the raw fuel medium to institute and maintain the complete conversion by gasification *in situ* of a mineral fuel deposit. When managed properly, short-duration electrical heating, which utilizes conductivity of the fuel deposit, will give relatively rapid development of such linkages. Known as *electrolinking*, this creates a system of fractures and forms a fixed carbon route along which the electric current can move preferentially rather than on a course governed by the electrolytical conductivity of the fuel mass. If this were not so, the temperature rise in the fuel bed would be limited by the evaporating temperature of electrolyte. Electrolinking affords a means of conducting subsequent gasification through a medium such as coal. In the case of oil accumulations in depleted sands, it may afford channels to stimulate the movement of oil to a well bottom.

Electrocarbonizing: Converting a fuel material *in situ* (at least in part) by electrical heating of relatively long duration is known as electrocarbonizing. When volatile constituents of coal such as byproduct tar compounds and ammonia liquors are released by this process, the physical-chemical changes wrought are essentially those occurring in a coke-oven plant. In fact, a buried coke composed of fixed carbon and ash is formed and a gas of 500 to 550 Btu per cu ft is generated from the volatile matter. This valuable gas comprises about 25 pct of the economic potential of the fuel deposit. Like the so-called byproduct tar compounds and ammonia liquors, it can be delivered to the surface.

Electrocarbonizing also forms the linkages, or channels, necessary if the fixed carbon of the coal is to be obtained by subsequent gasification with air, oxygen, or steam. Electrocarbonizing therefore serves two functions: it increases permeability and it yields volatile hydrocarbon compounds. Thus it will leave *in situ* a residue of coke (fixed carbon and ash) as a channelized fuel bed readily amenable to later subsurface gasification treatment or to subsequent exploration by ordinary strip mining methods.

Electrogasifying: The electrogasifying phase of underground electrocarbonization entails simultaneous electrical heating and injecting of air, oxygen, or steam through the fuel medium *in situ*. In reality it is a combined activity whereby volatile hydrocarbons are produced by electrocarbonizing while additional gases are derived simultaneously from the fixed carbon of the deposit by means of a gasifying process that sweeps air, oxygen, or steam through the linkages in the fuel mass.

The electrogasifying procedure will yield a gaseous mixture from the subsurface fuel deposit which is the equivalent of enriched producer gas or water gas. It is apparent that if this phase is carried to completion in the case of any amenable deposit, all the potential fuel constituents will have been liberated and obtained. The noncombustible rock matter or ash, seldom an economic substance, offers no problem of disposal as it has been left buried.

The following procedure for underground electrocarbonization of a coal deposit will aid the reader to grasp the process as a whole. Except for some pertinent modifications, similar treatment is applied to other types of fuel deposits.

Drilling of Boreholes: At least two boreholes are drilled so that the coal seam can be contacted from the surface. Maximum horizontal distance between boreholes during the pilot-plant experimentation at Hume, Mo., was 60 ft. Test data indicate, however, that for commercial purposes separations up to 500 ft or more would be feasible. Usually the depth to which holes must be drilled to reach the fuel deposit is not critical to successful operation of the process.

Table I. Carbon-Bearing Deposits of the Western Hemisphere

Deposits	Millions of Short Tons
Coal, All Ranks[1]	2,120,480
Oil from Oil Sands and Tar Sands	
United States[2]	113
Canada (Athabasca), minimum**	8,744
Canada (Athabasca), maximum**	26,230
Total minimum	8,857
Total maximum	26,342
Oil from Oil Shale	
United States, Green River formation, northwest Colorado only	
Mahogany ledge†	13,584‡
500-ft thick measure†	83,250‡
Brazil, Iraty black shale[5]	87,300‡
Total (using 500-ft measure for United States)	140,550
Oil from Oil Reservoirs	
Crude oil only	
United States[6]	4,155
Canada[7]	297
Mexico[7]	343
Venezuela[7]	1,485
All other countries in western hemisphere	194
Subtotal	6,474
Natural Gas Liquids	
United States[6]	645
Western Canada[8]	8
Subtotal	653
Total Oil from Oil Reservoirs	7,127

* Fifty percent of measured and indicated reserves of bitumen from bituminous sandstone in deposits near Vernal and Sunnyside, Utah; Casmalia, Santa Cruz, and Edna, Calif.; and Uvalde, Texas.[3]

** Fifty percent of estimated reserves in 8000 to 30,000 square miles.[3]

† Partly blocked and inferred oil shale. Resource reserve figures based on 66 pct net recovery from mining and retorting.

‡ Reserve figures based on 66 pct net recovery from mining and retorting.

Insertion of a Pipeline System: Piping is placed in the drillholes to reach from surface to coal seam. During pilot-plant tests boreholes were of 6-in. diam to accommodate the 2½-in. steel pipe used. An electrode or shoe of 4½-in. stainless-steel pipe was connected to the lower end of the tubing of each hole before it was placed in the hole. The pipe system serves as an electrical contact and also conducts the evolved gas to the surface. Necessary connec-

tions, pipelines, and receivers must be established, therefore, in the unit on the surface.

Applying Electrical Power: Electrolinking requires electrical energy of relatively high voltage to begin the desired reactions, but as carbonization continues voltage must be reduced, since the buried fuel deposit assumes new electrical characteristics through progressive changes caused by heating and by linkage attained between boreholes. These variations require installation of multiple-range transformers and related control devices. During the pilot-plant research at Hume, Mo., 2400-v ac was secured from a high-line transmission system and transformed to lower voltage as needed.

Transmission of Compressed Air, Oxygen, or Steam Through the Heated Fuel Mass: The heat generated by electrical resistance is sufficient to start a reaction, and by injecting atmospheric gases or steam down one well pipe and withdrawing or discharging through the other hole of the two-hole system, it is possible to create a progressive gasification through the interconnecting channelways within the seam. At the bottom of the intake pipe the gasifying medium, such as air, reacts with the fixed carbon to yield chiefly carbon dioxide gas. This material then is converted by endothermic reaction to a carbon monoxide gas mixture as it moves through the additional coke of the seam toward the discharge hole where it will be conveyed to the surface. Air, oxygen, or steam injection is continued until the original fuel material has been progressively affected.

Gas Storage and Associated Facilities: Economic disposal of products yielded by an underground electrocarbonization process of industrial dimension will require a surface plant and conveniences.

Underground Electrocarbonization of Coal

Experimental Procedures: Laboratory experimentation was made on a large sample of bituminous coal from the Melbourn seam which occurs on the property of Sinclair Coal Co. at Hume, Mo. The primary purpose of this work was to ascertain basic data as a subsequent guide in pilot-plant research. The following controlling factors were deemed most important:

1—Magnitude of electrical resistivity of the coal. The resistivity defined the size and voltage range of the electric transformer required.

2—Critical current density necessary to breakdown electric resistance of the coal. This was essential for estimating the size of the power unit.

3—The quality and quantity of gas produced by the process. Measurement of gas volume and Btu content was a means of evaluating general economics of the procedure, or in other words, determining the ratio of input-energy to output-energy.

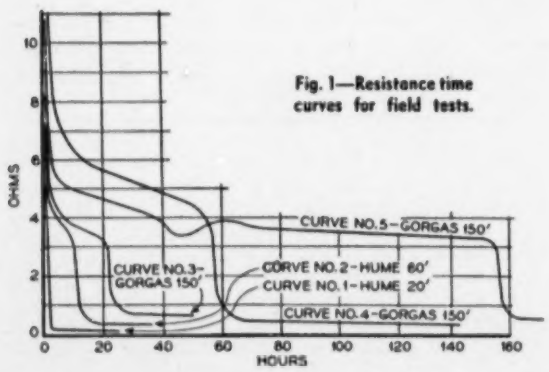

Fig. 1—Resistance time curves for field tests.

Laboratory experiments progressed to successful completion and gas of good Btu value was obtained. It was further demonstrated that under controlled conditions electrolinking could be accomplished in small samples. Also it was shown that the coal could be channelized for subsequent gasification with air, and it was determined that cylindrical electrodes operated with approximately 0.10 to 0.15 amp per sq cm were required to start the process of electrolinking in laboratory samples.

The first field study of underground electrocarbonization was conducted at the Tiger mine of Sinclair Coal Co. where a coal seam lying about 20 ft below the surface was tested. Contact to the coal bed was made by means of insulated electrodes placed in boreholes. Electrical connections were made on the surface to the secondary of a 500-kva, 2400-v transformer. When electric current was applied for approximately 4½ min a very rapid drop in resistance demonstrated that it was possible to duplicate the laboratory tests in the pilot-plant. The tests showed also that voltage control of the secondary of the transformer was absolutely required and that 2400 v was sufficient to accomplish the necessary field operations.

Following the initial success, a second experiment was started with improved equipment. To control the secondary voltage applied to the electrodes, a water rheostat was built. The design of the electrodes was modified so that each could serve not only as a current conductor but also as a gas collector and an air-lift pump. In this second experiment the operation was started by application of a controlled electrical current to electrodes spaced 20 ft apart. The pre-heating or pre-linkage period was about 65 min, during which time resistance in the fuel mass between boreholes was reduced from 7 to approximately 5 ohms. At the end of this time, electrolinking occurred and there was a very sharp drop of resistance to about 2 ohms. The electrocarbonizing phase then was initiated by continued application of electric power, with an accompanying decrease in resistance. This test resulted in production of a very satisfactory gas having a heating value of 525 Btu per cu ft, demonstrating the feasibility of correlating field and laboratory data.

The conclusions reached as a result of the first two field investigations were: 1—A coal deposit can be treated *in situ* by an electrocarbonizing procedure. 2—An electrical potential of 2400 v is satisfactory to initiate electrolinking. 3—Electrolinking in the coal seam will induce channels through which air, oxygen, or steam can be moved and reacted between one borehole and the next. 4—A gasification process by air, oxygen, or steam can be started after the electricity is stopped. 5—A satisfactory gas can be produced by the process of electrocarbonization as a whole.

To extend the scope of further experimental field work beyond the physical limits imposed by use of the water rheostat, a special autotransformer rated at 500 kva with secondary taps down to 200 v was purchased. This transformer, which was capable of giving full kva output down to 800 v, also would deliver 240 kva when operated at 200 v. In addition, several indicating and recording instruments were obtained for measuring electricity and gas. Prohibitive expense during the field tests did not permit

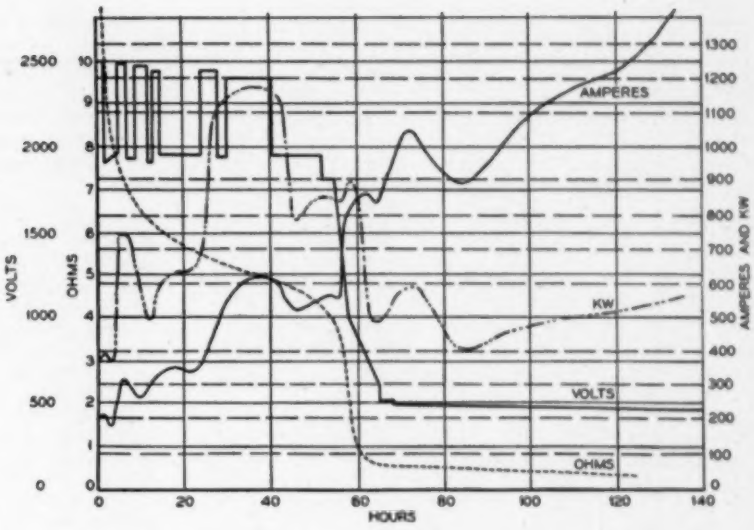

Fig. 2—Power requirements for electrolinkage as related to time curves for voltage, amperage, and kilowatts. Ampere and kilowatt curves follow closely what would be expected from the voltage changes that took place. Electrolinking was accomplished in about 58 hr, after which the electrode potential was reduced to 500 v.

installation of either an electro-filter or a gas exhauster. However, the operation of a full-scale industrial plant, where complete recovery of tar compounds is economically necessary, would require an electro-filter in the system and withdrawal of gas from the subsurface fuel bed by an exhauster.

As a result of continuing experiments at Hume, Mo., successful electrolinking and electrocarbonizing of the coal seam ultimately was obtained with electrode spacing of 60 ft. In this final experiment, resistances decreased from 11 ohms to approximately 7 ohms in a period of 12 hr. At the end of this time electrolinking was accomplished and the resistance dropped very rapidly to less than 0.4 ohm. It continued at this low value throughout the test.

In 1951, Sinclair Coal Co. and the U. S. Bureau of Mines developed an agreement to apply the electrocarbonization process at Gorgas, Ala. Electrical equipment was moved to Gorgas where the process was applied to make a fire-drift or channel in a coal bed previously used for gasification research by the USBM.

The data secured from the Gorgas experimentation have been weighed and analyzed with those obtained earlier at Hume. They have been plotted comparatively on Fig. 1.[20] Curves No. 1 and 2, for data taken at Hume, represent results of tests where the electrodes were spaced at 20 ft and 60 ft respectively. Curves No. 3, 4, and 5 are from records obtained at Gorgas, where in each case the electrodes were 150 ft apart. Of the latter three curves, No. 3, which shows that electrolinkage was accomplished in about 21 hr, or at a rate of about 7 ft per hr, is believed to be the most typical expression of what might be expected from large-scale or industrial operations. This is because the relatively long preheating (pre-linking) time shown in curves No. 4 and 5 is due to the fact that one electrode in each of these tests was in, or very close to, a carbonized area that had resulted from prior tests at Gorgas. Such previously carbonized areas tended to expand the equivalent diameter of the electrode to an extent where current density values were reduced below the point required to penetrate through the coal seam and accomplish electrolinking. These abnormally large electrodes required long times and large kw-hr input to secure sufficient heat through the central path to break down the fuel bed.

Fig. 2 illustrates the power requirements of electrolinking as related to time curves for voltage, amperage, and kilowatts. The ampere and kilowatt curves follow closely what would be expected from the voltage changes that took place. Electrolinking was accomplished in about 58 hr, and then, to maintain a reasonable current on the electrodes, it was necessary to reduce the electrode potential 500 v.

Data and test results indicate that an ideal power source for a full-scale commercial underground electrocarbonization process should be approximately 2000 kva, with a secondary voltage regulation from 4000 to 400 v. Such control should give an optimum current density on the electrodes and a resultant maximum penetration through the coal seam at a minimum power cost to accomplish the electrolinking phase of the process.

Concerted efforts were made to determine the size and shape of the underground gasified area which resulted from the electrocarbonization field research. This was important because a knowledge of the character of the area would give not only a better understanding of the underground gasification technique, in general, but would also guide proper layout and hole distribution of a full-scale, multi-electrode project designed to treat and convert the maximum amount of coal. In as much as the field tests at Hume had been made in shallow coal, it was possible to expose the treated bed by stripping the cover with a dragline and thus ascertain the pattern of the affected zone *in situ*. At Gorgas, where the fuel bed occurs beneath about 200 ft of overburden, it was not economically possible to open the ground for a direct view, and the extent of the gasified area was defined by means of a modified zero potential electrical method. In both cases, at Hume and Gorgas, the pattern of the affected areas was similar to the shape of a crudely center-swollen but attenuated and lengthened ellipse. Fig. 3 illustrates typical gasification patterns developed by uniflow action. In such an operation the air, oxygen, or steam used as a gasifying medium is swept or blown continually in one direction from an intake borehole toward a second or exhaust hole. Thus there is no reversal of direction. Although this method of uniflow motion has produced gas of higher Btu in greater quantities than has ever been done before, analysis of the gas indicates that at

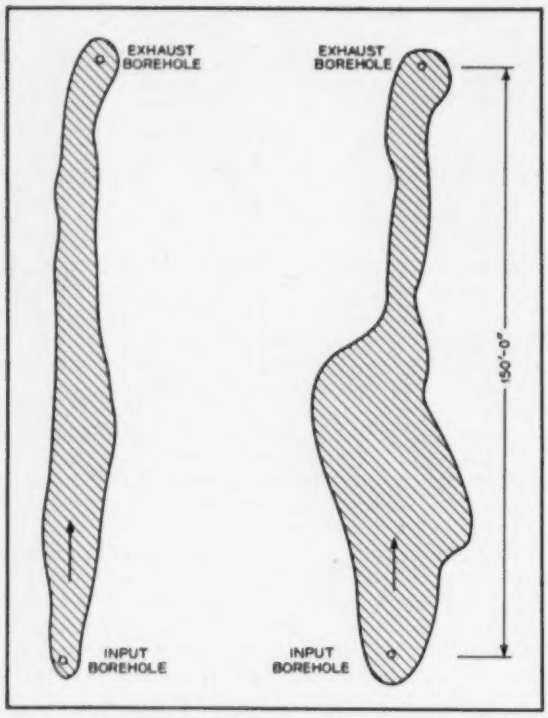

Fig. 3—At left, gasification pattern when oxygen and steam are used in uniflow operation. At right, typical gasification pattern when air is used in uniflow operation.

least 10 pct of the potential carbon dioxide was still not converted into carbon monoxide, as would be the case if it were recycled or passed secondarily over a hot coke bed. Recycling probably could be accomplished if some method of reverse flow were put into effect. Reverse flow also would cause the shape or pattern of the gasified zone to change to a more uniform or symmetrical outline which would increase accordingly the recoverable tonnage of coal lying between any two electrodes. At the present time there are not enough experimental data to permit full comparison between the uniflow and reverse flow methods.

Summary and Economic Aspects

The fundamental advantages of electrocarbonization are: 1—relatively low construction and installation cost, 2—comparatively low cost of operation and maintenance, 3—simple regulation and good control, 4—high efficiency and therefore good economic yield, and 5—handling of noncombustible matter is eliminated.

Though the economics of the process depend on many factors such as cost of power, depth to fuel bed, thickness of seam, and proximity and character of industrial activities, research has demonstrated that underground electrocarbonization of coal probably can be conducted profitably and with success. From the labor standpoint alone, it should create more pleasant and less hazardous jobs and institute new potentialities in the coal industry. The compilation of a cost analysis to illustrate the operating economics of a large-scale commercial plant comprising 30 to 50 underground linkages indicates that it is reasonable to expect production costs of about 10¢ per 1 million Btu.

The growing development of gas turbine installations and the ever increasing demand for electric power may lead to the first commercial adaptation of the process of underground electrocarbonization of coal. For example, the use of low Btu producer gas in turbines already has been studied by both the General Electric Co. and the Westinghouse Electric Corp.:[11]

> On July 29, 1952, an agreement was reached between United States Steel Corporation and Westinghouse Electric Corporation for the erection of a combustion test system at the former's Carrie Furnace of the Homestead District Works. The purpose of this test program was to explore the possibilities of burning blast furnace gas in an internal combustion gas turbine and to develop suitable equipment for such an application.
>
> Initial tests of the combustion design indicated that modifications to the gas admission nozzle were required to improve combustion and flame stability for full and part load operation.
>
> The tests indicated that blast furnace gas can be ignited and burned with efficiencies comparable to those obtained when fuel oils or gases with higher heating values are used in gas turbine combustors.

Operating gas turbine topping units in combination with secondary-load gas turbine systems or low-pressure steam units offers attractive possibilities for generating large blocks of electric power. Generating stations and manufacturing plants, when located in the field at the place of electrocarbonization of raw fuel *in situ*, will inhibit uneconomical movement of gas away from the site by pipeline.

Fig. 4 demonstrates the relative costs of transmitting energy in the form of electricity and coal. It is assumed that 1 ton of coal equals 25 million Btu and 1 kw-hr equals 12,500 Btu. Thus 10¢ gas is equivalent to $2.50 coal. As the costs of transmitting

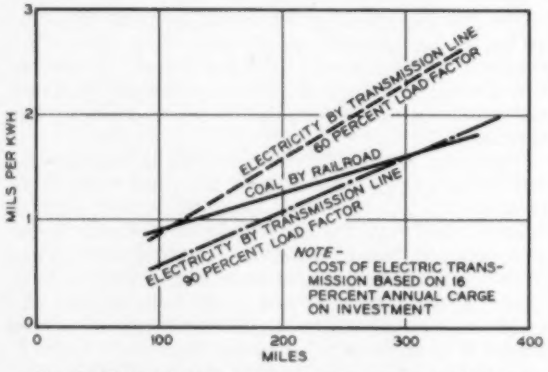

Fig. 4—The relative cost of transporting energy in the form of electricity and coal.

energy are chiefly those of investment, the cost is almost inversely proportional to the load factor and almost directly proportional to the annual charge. The effect of load factor on transmission costs is shown by two curves in Fig. 4; at 60 pct load factor electric transmission is cheaper up to 100 miles, and at 90 pct load factor the curves cross at a distance of approximately 350 miles.

The gasification of a coal seam *in situ* after it had been preliminarily channelized by electrolinking was investigated at Gorgas, Ala., by the USBM. The results obtained by such experimentation have been published by M. F. Fies and J. L. Elder[12] and Tables

II, III, and IV, which follow, have been taken from their publication.

Industrial application of underground electrocarbonization of coal will be determined by the relative cost of the process as expressed in equivalent fuel units and in the comparative availability and character of other competitive types of raw fuel materials.

As mentioned before, oil shale is an important potential source from which petroleum compounds can be derived whenever they are required industrially. The treatment of oil shale *in situ* is an attractive engineering problem; indeed, the general process of underground electrocarbonization first was conceived and applied as a means of securing oil from oil shale, and early research of electrocarbonization was carried out by Erich Sarapuu in the Mining Academy, Freiberg, Germany.[18] Composition of shale used for the first experiments was as follows (Fisher analysis):

Tar	42.10 pct
Moisture	6.80 pct
Fixed carbon	43.30 pct
Gas	7.80 pct
Total	100.00 pct

As is the case in converting buried coal masses by electrocarbonization, the oil shale deposit is prepared for treatment by drilling boreholes into which pipelines are inserted. In general, ground conductivity is a function of the following variables: 1—type of soil, 2—definite anisotrophism of the formation, 3—chemical nature of salts in the electrolyte, 4—temperature of the soil, 5—concentration of salts in the electrolyte, 6—closeness of packing and rock pressure, and 7—moisture content in the rock.

Visual observation in the laboratory of the process of electrolinking of oil shale, using electrode spacing of about 10 cm (4 in.), showed clearly that electrolinking is an electrical activity comprised of two phenomena occurring almost simultaneously, namely, electric arcing and resistance heating. The current, following the least resistance in a rock containing hydrocarbons, creates minute arcs along the path of the current. The fixed carbon which is liberated at arcing temperature forms a fixed carbon zone for resistance heating. The speed of linking is a function of the electric power applied. This cannot be explained as *dielectric puncturing*, wherein the breakdown potential would be proportional to the breakdown distance or voltage gradient (volts per unit distance). Some of the laboratory data showing the characteristic effects of electrode spacing on electrolinking are as follows:

Electrodes Spaced at 10 Cm		Electrodes Spaced at 5 Cm	
v	ma	v	ma
1000	8.5	1000	16
1500	10	1500	25
2000	12	2000	32
2500	13	2500	50
3000	15		
3400	27.5		

These data demonstrate that resistance is affected by electrode spacing. In actual field practice, however, the resistivity changes that transpire over large distances tend to reduce this effect to zero, but good

Table II. Operating Results, Gasification With Air[12]

System	Boreholes XII-XIII	Boreholes XIV-XV	Boreholes SIV-XV
Length, ft	152	155	155
Inlet	Borehole XI or XII	Borehole XIV	Borehole XIV
Outlet	Borehole VIII	System VIII-XII	System VIII-XII
Operating time, days	93	59	21
Air input, cfm*	1195	1160	1890
Gas output, cfm*	692	1171	2157
Input air pressure, psig	8	30	27
Input air leakage, pct	48.1	13.8	5.2
Properties of product gas			
Analysis, pct			
Carbon dioxide	11.9	10.5	9.7
Illuminants	0.3	0.3	0.3
Oxygen	0.5	0.9	0.5
Hydrogen	7.6	8.4	9.2
Carbon monoxide	7.1	10.7	13.1
Methane	1.8	1.8	1.5
Nitrogen	70.8	67.4	65.7
Heating value, Btu per cu ft*	71	86	93
Moisture content, mol water per mol dry gas	0.21	0.15	0.11
Rate of coal utilization** basis of moisture and ash-free coal, tons per day:			
Completely gasified	2.07	5.79	11.15
Carbonized only	8.92	11.29	15.94
Total affected	10.99	17.08	27.09
Total coal utilized** basis of moisture- and ash-free coal, tons:			
Completely gasified	193	342	235
Carbonized only	829	667	329
Total affected	1022	1009	564
Usage and production per ton of moisture- and ash-free coal completely gasified:			
Air used, M cu ft	831	289	243
Gas produced, M cu ft	481	292	278
Heat of combustion of gas, Btu x 10^6	34.2	25.1	25.8
Energy required for air compression,† Btu x 10^6	4.6	4.5	3.6
Net energy produced, Btu x 10^6	29.6	20.6	22.2

* 60°F, 30-in. Hg pressure, dry.
** Calculated from material balances.
† An adiabatic efficiency of 75 pct is assumed for air compression. Power is to be produced from the product gases and it is assumed on conversion to electrical energy, 11,000 Btu will be required per kw-hr.

Table III. Operating Results, Gasification With Oxygen[12]

Operating time, hr	36
Oxygen input rate, cfm*	604
Properties of effluent gas	
Analysis, pct	
Carbon dioxide	47.8
Illuminants	0.3
Oxygen	0.2
Hydrogen	24.5
Carbon monoxide	21.2
Methane	4.1
Nitrogen	1.9
Heating value, Btu per cu ft	195
Specific gravity	1.0
Moisture content, mol of water per mol of dry gas	0.34
Effluent gas flow, cfm*	1335
Cu ft of oxygen per M of make gas	452
Cu ft of oxygen per M of (CO + H_2)	990
Cu ft of oxygen per million Btu in the product gas	2320
Rate of coal utilization, basis of moisture-and ash-free coal, tons per day**	
Completely gasified†	33.1
Carbonized only	0

* Measured at 60°F, 30-in. Hg, dry.
** Calculated from material balance.
† This is fresh coal plus coke from previous gasification with air, all calculated as equivalent coal.

Table IV. Water Gas Production, Average Operating Results for 12 Consecutive Cycles[12]

Item	Air Blow	Steam Run
Average length of period, hr	18.8	4.2 (3.85 to 5.08)
Input air rate, cfm*	1250	
Input steam rate, lb per hr		varied from 1200 to 2100
Gas production, cfm*	1800	585
Properties of effluent gas		
Analysis, pct		
Carbon dioxide	12.6	20.8
Illuminants	0.3	0.4
Oxygen	0.3	0.4
Hydrogen	13.4	47.9
Carbon monoxide	10.4	12.0
Methane	2.8	7.6
Nitrogen	60.2	10.9
Heating value, Btu per cu ft	112	279
Specific gravity	0.92	0.62
Moisture content, mol water per mol dry gas	0.19	0.56

*At 60°F, 30-in. Hg, dry.

contact between the oil shale and electrode always is of marked importance.

Electrogasifying appears to be a suitable comprehensive method for the treatment of oil shale *in situ*. It involves electrical loosening of the formation to develop reaction channels; the conversion then can be continued by combustion of fixed carbon. The several temperature levels formed in the fuel bed in thick and/or intercalated oil shale deposits can be used as heating elements for continuous carbonizing of surrounding oil-bearing material. Electrical carbonizing should be used as long as economically feasible, before the air is introduced and the fixed carbon burned. The economic limit varies as a function of the oil content in the oil shale and the cost of available electricity.

Additional field experimentation with electrocarbonization of buried oil shale must be done and extensive research accomplished before it will be possible to apply the process on an industrial scale. Preliminary laboratory tests[14] made on a sample of brown coal indicate that results may be achieved which are broadly similar to those obtained by treating oil shale.

Application of the general process of electrocarbonization for stimulating and increasing the recovery of crude oil from stripper fields, depleted oil pools, and tar sand deposits such as at Athabasca, Canada, was recognized by the authors when research on underground gasification of coal was begun in September 1947. The procedure, which may be classed as a *tertiary recovery* method for securing oil by subsurface electrical heating, is of such unique character as a phase of electrocarbonization that it has been named the *electrotherm* process. Since even the most specialized methods of secondary recovery as applied in oil reservoir rocks commonly fail to secure more than 60 pct of the potential oil, this electrotherm process, which can extend this production ratio, is important and merits distinction.

The first subsurface electrical treatment of oil sand was performed by Sarapuu[14] on material from Elsas Lothringen, where the famous French oil sand mines are located. This laboratory experimentation was done by extensive heating, and for practical purposes the oil was distilled and procured in gaseous form. This was possible because of the low electric resistance of residual fixed carbon in the oil sand. Further laboratory investigations were made in the mining engineering department at Missouri School of Mines in the period from 1947 to 1951 when several researchers[16-17] studied the behavior of oil sands subjected to electrical heating and combustion. This laboratory research created marked interest, and, apparently as a result, C. M. Davis[16] and Trevor W. W. Hill[18] subsequently undertook to carry on their own research elsewhere.

The results described by Davis and Hill appear to follow the general pattern of those which attend the electrotherm process. However, the authors of this paper cannot agree with their re-theorizing of the process. Their attempts to explain the phenomena of electrocarbonization as being primarily that of dielectric breakdown are not in accordance with the proved scientific facts. The new terms they propose, such as *pyrovolatilization*, *electrovolatilization*, and *dielectric heating*, actually are synonyms of *electrolinking*, *electrogasifying*, and *electrocarbonizing*. In general terms, it appears that the breakdown they ascribe to dielectric heating is one resulting from mechanical failure of insulators in the system. Electrocarbonizing is not a localized phenomenon, and it may extend through the raw fuel deposit for several hundred feet. It is a process whereby the chemical nature of the raw material is changed, and thus the original high resistivity is reduced. Electrocarbonizing is a resistance heating and cannot be explained as dielectric heating.

Although adaptation of the electrotherm process is feasible, there are several aspects that make the process somewhat different from that of electrocarbonization which applies to the treatment of coal *in situ*. For example, the primary aim with petroleum-bearing deposits is to secure the production of liquid substances rather than gaseous materials. Also, geological environments and modes of occurrences of oil-bearing deposits commonly are much more diversified than those of coal, and this results in a need for applying special techniques to individual oil pools. Tertiary recovery methods of oil field exploitation are predicated on the use of the thermal energy to provide a means of driving hydrocarbon fluids from the reservoir rock. That is, if enough energy in the form of heat can be injected into the deposit, it will provide necessary expulsive forces to drive some of the fluid from the reservoir.

The advantages of the electrotherm process in oil recovery are the complete controllability of the operation and the opportunity to concentrate a range of heat in the reservoir rock at a given well location. The application of heat will produce oil progressively, and this can be done most effectively in two or three stages. Each successive rise of temperature should begin when further recovery is no longer possible at the previous stage. For example, low-temperature heating will induce fluidity and will dissipate congealed hydrocarbons that often inhibit the movement of liquids through the rock. Surface tension of oil and the interfacial tension between oil and water will be reduced. Thus it is apparent that low-range heat may stimulate recovery from stripper wells or from otherwise depleted sands.

When the high temperature of electrotherm treatment is required, the electric current is passed directly through the oil reservoir and the extent of heat penetration is greater than that given by other methods. High temperatures fracture the oil-bearing rocks; viscosity is lowered; and the evaporation of fluids supplies additional energy which in turn, by disturbing the equilibrium in the reservoir, will support and increase the flow.

It is possible that the most economical industrial process ultimately may be found to involve contemporary electrogasification and distillation of the oil. That is, it may be desired commercially to accomplish stages of tertiary recovery by utilizing temperatures of various ranges. The heating should be done in a continuous cycle until complete recovery of the hydrocarbon potential eventually is obtained by electrogasification. The electrodes to be used must be designed, of course, to withstand the temperatures that will be required to accomplish the whole cycle.

To summarize, it may be noted again that the geological environments and modes of occurrence of oil deposits are so numerous and diversified that it is impossible to prescribe a treatment that will apply to all cases. However, electrocarbonization as a whole, or as it is here designated, the *electrotherm process*, is a very flexible method and can be used as follows:

1—To stimulate recovery of oil from stripper fields or depleted pools by melting and removing the con-

gealed hydrocarbon constituents in the sands that otherwise restrict and inhibit the flow of oil to well.

2—To stimulate the recovery from depleted fields and stripper areas by means of electrical heat to induce the development of linkages and channels in the reservoir rock.

3—To stimulate the flow of oil from highly viscous oil sand deposits by the gasification, in part at least, of residual oil.

4—To secure gaseous hydrocarbon compounds from depleted fields after all other production methods have been applied and exhausted. This process entails complete gasification *in situ* by use of electrical heat.

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Depth Determinations by Electrical Resistivity

by Harold M. Mooney

RESISTIVITY measurements for determining depth to bedrock, water table, and other geologic discontinuities have had only limited success. Many of the difficulties can be attributed to complex geology and to basic limitations of the method; current flow through a continuous medium is a diffusion phenomenon, emphasizing irregularities near the source and smoothing out those at a distance. Some of the failures, however, are due to careless field work and incompetent interpretation. A forthcoming publication[1] may help to reduce difficulties of this sort.

The writer here attempts to bring order into the multiplicity of interpretation methods and, to a limited extent, to evaluate them. For all methods, the field data to be interpreted consist of apparent resistivity values plotted against electrode separation, Fig. 1. The interpretation should give depths to one or more geologic horizons. Direct currents and the Wenner four-electrode configuration will be assumed, since these are widely used, although the interpretation problems remain essentially the same for other electrode configurations. Alternating currents higher than, say, 20 cycles per second introduce complications beyond the scope of this paper.

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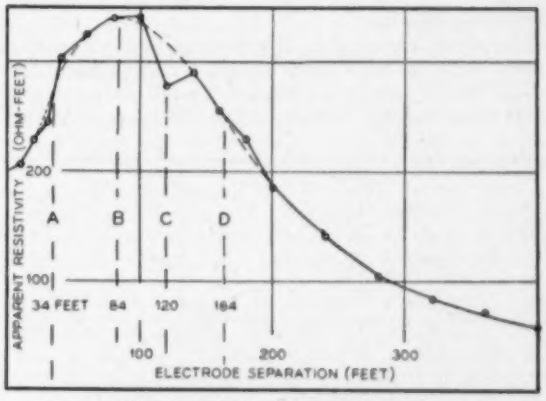

Fig. 1—Typical resistivity field data.

Three approaches to the interpretation problem have been used. These may be called empirical, theoretical curve matching, and direct. Many techniques have been proposed, but each can be reduced to one of these approaches and to a single geologic idealization. This idealization rests on the following assumption: the earth in the limited volume of interest can be approximated by a horizontal sequence of layers, each homogeneous and isotropic in its electrical properties. This seemingly restrictive assumption has proved to have practical value, although future work should aim at removing some

of the restrictions. An attempt in this direction forms the subject of a separate paper.[3]

The field curve normally shows maxima, minima, points of inflection, and breaks (sudden changes in slope). Empirical methods select some such characteristic and equate the corresponding electrode separation to the depth to a discontinuity or to a fraction thereof.

The first and most widely used empirical method was proposed by Gish and Rooney.[4] They equate the depth to the electrode separation at which a maximum or minimum occurs. (In Fig. 1, depth B = 84 ft). Lugeon and Schlumberger[4] prefer three-fourths of this electrode separation. (In Fig. 1, depth B = 63 ft). The method can give order-of-magnitude results over a restricted area, provided the multiplying factor is established by drill control.

A common perversion of this technique uses breaks in the curve rather than maxima or minima. (In Fig. 1, depth C = 120 ft). Such breaks can be due only to lateral changes, electrolytic phenomena, or instrumental troubles. They can not be due to the vertical changes of interest.

Lancaster-Jones[5] takes a point of inflection as the observable characteristic. He equates the depth to two-thirds of the corresponding electrode separation. (In Fig. 1, depths A and D = 23 and 109 ft). Palmer and Hough[6] point out that this applies to only a single discontinuity and a particular ratio of resistivities. They extend the technique to other cases, but recognize that it has limited application.

Another group of empirical methods modifies the field curve before it is interpreted. A suggestion of Moore[7] has aroused some controversy. Moore's cumulative resistivity method requires data taken at equal increments of electrode separation. For each separation he plots as the measured quantity the sum of that reading plus all preceding apparent resistivity readings. He draws straight lines through the resulting points, and equates electrode separations at the line intersections to depths to discontinuities, Fig. 2.

In effect, Moore plots the integral of the apparent resistivity curve. This produces a smoothing of the data, which can be justified for some purpose, and a greatly reduced vertical scale. The interpretation

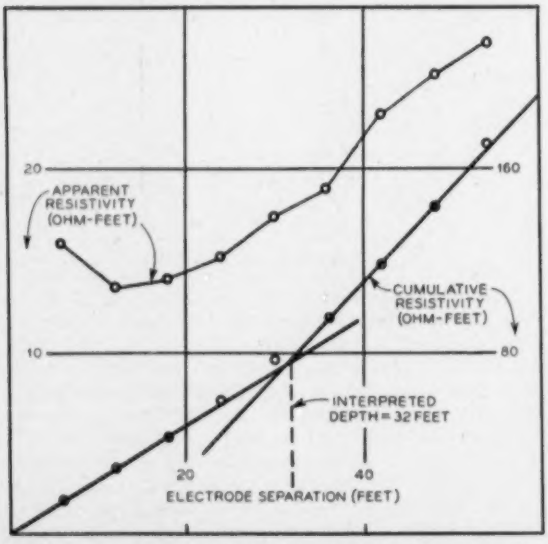

Fig. 2—An example of resistivity interpretation by Moore's method.

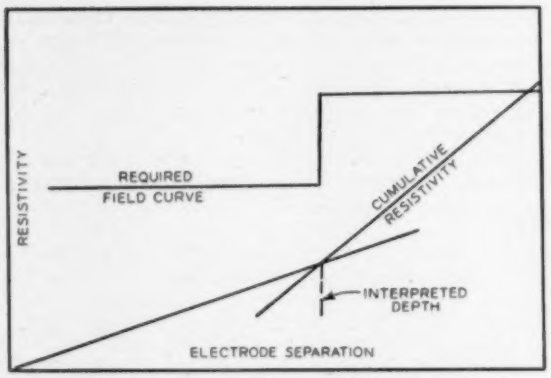

Fig. 3—One implication of Moore's method of interpretation, in an ideal situation.

based on straight lines makes no theoretical sense, however, as Muskat[8] has shown and as Moore readily admits. The simplest integral curve, that of two intersecting straight lines, would be produced by an apparent resistivity curve consisting of two horizontal segments (constant apparent resistivity), abruptly offset, Fig. 3. No such curve has been observed or predicted. The Moore method probably reduces to a modified Gish-Rooney technique, with possibly some advantage through smoothing. Ruedy[9] has proposed a theoretical justification for Moore's method, but it is hard to see how his conclusions follow from his data.

A second method which modifies the field data has been suggested by Barnes.[10] The analysis is obscure and unnecessarily complicated, but Rogers[11] has shown that he plots an approximation to the reciprocal slope of the conductivity depth curve. The interpretation reverts to the Gish-Rooney method.

Other methods have been proposed which require graphical differentiation of the field curve. This gives sharper indications but emphasizes accidental irregularities. Potential drop ratio methods approximate this scheme; data can be interpreted by curve matching or empirically. For empirical interpretation, depths are set equal to those electrode spacings where the field curve passes through a standard value. This is no better and no worse than the Gish-Rooney method.

Given an assumed sequence of layers, with specified thicknesses and electrical properties, a theoretical resistivity curve can be calculated. A variety of such assumptions will yield a family of curves. If the field curve can be shown to match some one of this family, then the actual geology presumably approximates the idealized conditions used in calculating the curve. The quality of the match provides a rough confidence estimate.

The field curve and the type curves can be plotted on either a linear (cartesian) or a logarithmic scale. According to Heiland,[12] the Schlumberger organization at one time used direct curve matching on a linear scale. A more widely used linear method was proposed by Tagg.[13] Starting from calculated curves for a single horizontal discontinuity, he describes a trial and error process which yields depth and resistivity values. The method requires an independent determination of surface resistivity. Later proposals have eliminated this requirement by using apparent resistivity ratios. A later paper by Tagg[14] and papers by Rosenzweig[15] and Longacre[16] describe methods of this sort. All of these require extensive analysis to interpret each field curve.

The logarithmic scale has such obvious advantages that linear methods such as Tagg's should be abandoned. 1—The shape of the curve becomes independent of the units of resistivity or electrode separation. A single logarithmic curve can replace a large number of linear curves, since the latter must be replotted for each change in scale of the problem. Further, the interpreter can soon develop an intuitive feel for curve trends. 2—The problem of determining near-surface resistivity becomes easier, since the entire first portion of the curve can be used.

Specific suggestions for interpretation by logarithmic curve matching are given by Roman,[17] Wetzel and McMurry,[18] and particularly by Spicer.[1] Wetzel and McMurry also present tables for plotting two and three-layer curves. The same graph paper must be used for field and calculated curves; two-cycle log paper such as Dietzgen 340D-L23 or Keuffel and Esser 359-112L is recommended. Two, three, and four-layer curves will be made available by Mooney and Wetzel.[19]

Fig. 4 shows the field data of Fig. 1 on a logarithmic scale. Fig. 5 shows a group of three-layer theoretical curves. When curves are superposed, the best match occurs for the heavy curve in Fig. 5, which was calculated for resistivity ratio 1:3:1/10 and depth ratio 1:4. The unit axes cross the field curve at 97 ft (this gives depth to the second interface) and 192 ohm ft (surface resistivity). The complete interpretation gives two discontinuities, at depths of 24 and 97 ft, separating media with true resistivities 192, 576, and 19 ohm ft.

A field curve can rarely be made to match completely a calculated curve, because of the limited number of calculated curves available. Interpolation between them becomes necessary. Fortunately the properties of a logarithmic plot make this feasible. An experienced interpreter has a feel for the behavior of resistivity curves under various conditions; one important use for calculated curves, in fact, is to provide a sound basis for developing such a feel quickly.

Many field curves clearly represent four layers or more. A second problem which arises in curve matching is to interpret these by two and three-layer curves, until four-layer curves become available. The basis for the method was suggested by Hummel.[20] He proposes to reduce two surface layers to a single equivalent layer, using an analogy with parallel resistances in an electrical circuit. He notes that the approximation applies only for electrode

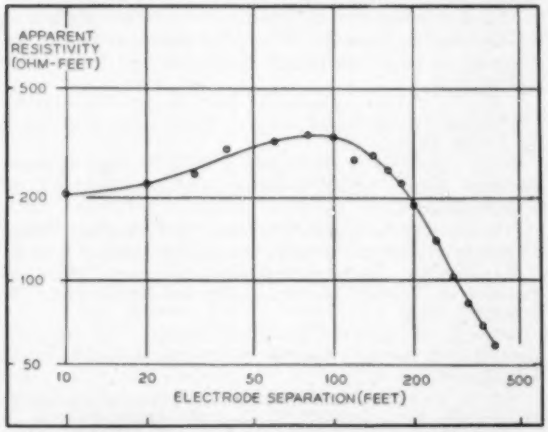

Fig. 4—Resistivity data of Fig. 1, replotted on a double logarithmic scale.

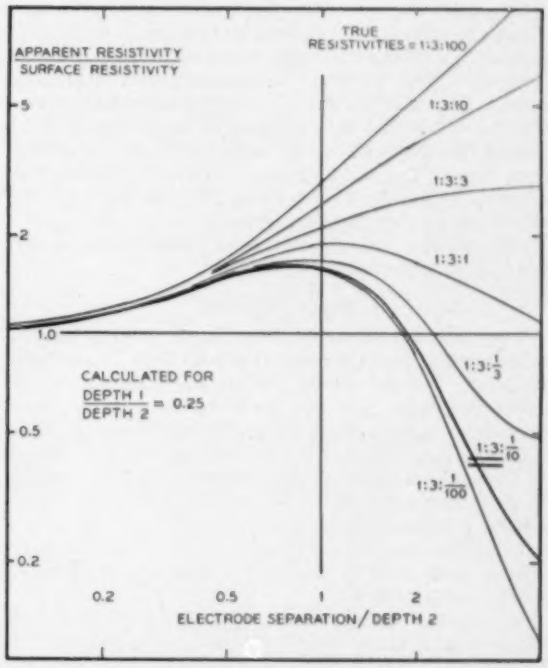

Fig. 5—A group of theoretical curves, calculated for one depth ratio and several resistivity combinations.

spacing that is large compared with the thicknesses of the two surface layers. Pirson[21] combines this with Tagg's method and a method of successive approximations. The fact that Hummel's rule can lead to serious error has been noted by Geneslay and Rouget.[22] Ebert[23] derives four such rules for the three-layer case, based on possible resistivity ratios in the layers; one of these reduces to Hummel's rule.

The use of Hummel's rule requires a partial match. For example, the first part of a three-layer curve can sometimes be fitted to one two-layer calculated curve, and the last part to another. Wetzel and McMurry[18] conclude that this may give fair accuracy when the three-layer curve has a minimum, but usually fails when it has a maximum. They point out further that two-layer data do not always represent a limiting case for a particular set of three-layer curves, but that the curves may in fact cross. Watson and Johnson[24] conclude that the second layer should be appreciably thicker than the surface layer to apply successfully a partial match.

Compared with empirical methods, curve matching has the following advantages: 1—It will usually give no answer rather than an incorrect one, in cases where the true geology deviates so widely from the assumptions that resistivity methods are inapplicable. This is an outstanding weakness of Moore's method, for example, which will almost always give some sort of result. 2—The entire resistivity curve, rather than localized portions of it, is used to obtain the geologic data. 3—The quality of a match provides an estimate for the reliability of an interpretation. 4—The method is theoretically exact within the assumptions, and the assumptions are clearly stated. Extensions of the method to less restrictive assumptions can be made with confidence. 5—For the two-layer case (the usual limit for empirical methods), curve matching is as simple as empirical technique and also faster, considerably more so than the Moore method.

The utility of curve matching should not be exaggerated, however: 1—Extrapolation between curves is usually necessary, which requires judgment based on experience. 2—Many field curves give no match at all. This may be due to failure of the field situation to satisfy the assumptions, or to carelessness in taking the data. Either lateral or vertical variations may cause the field situation to differ from the assumption; lateral variations can be detected by offsetting or rotating the spread.

Perret[25] and Petsch[26] give field comparisons of the various interpretation methods.

Direct Methods

Two interpretation methods have been proposed which work directly from the field data to geologic layering. No calculated curves are required as in curve matching, yet the methods have more theoretical basis than the empirical techniques.

Evjen[27] has proposed a weighting method which deals with image densities rather than with depths to discontinuities. The treatment can be kept rigorous to a later stage in the interpretation, yet it ultimately requires approximations which may or may not be satisfactory. Roman[28] mentions unpublished work on weighting.

Slichter[29] suggested a direct process based on an integral transform, and Pekeris[30] described the steps necessary to apply this to a layered earth. In calculation of potentials about a point source in a layered medium, this seems to bear the same relation to Evjen's proposal that the integral representation does to the image representation.

The steps required by Pekeris are: 1—Measure the potential distribution about a point electrode, by some necessarily indirect process. 2—Perform a numerical integration, involving the potential as one term, over distance from the electrode. 3—Interpret the results graphically in terms of resistivities and of depths to discontinuities.

The entire method has been investigated in some detail by Madden, Rogers, and Mooney.[31] A satisfactory field procedure was developed to yield potentials about a point electrode. Tables suitable for use on an electronic computer were calculated, based on a polynomial approximation, to carry out the numerical integration. The approximation of an infinite integral by a finite set of measurements proved particularly troublesome. The method was applied to nine sets of calculated potential data. Two alternatives to Pekeris' method were developed.

They concluded that: 1—The Pekeris method involves a restrictive assumption, namely that each layer must be thicker than the one above it. 2—For a multi-layer problem, accuracy for successive layers drops off sharply. This arises in part because the solution for each layer depends on all previous solutions. 3—The results for even the first layer are not consistently satisfactory. Of the nine cases mentioned above (two three-layer and seven four-layer), seven yielded a good solution for the top layer, but only two for the next layer. 4—The method is laborious, complicated, and hard to associate with the geologic problem.

These tentative results should not be taken as conclusive. Other groups now working on the problem may develop a fresh approach with more success.

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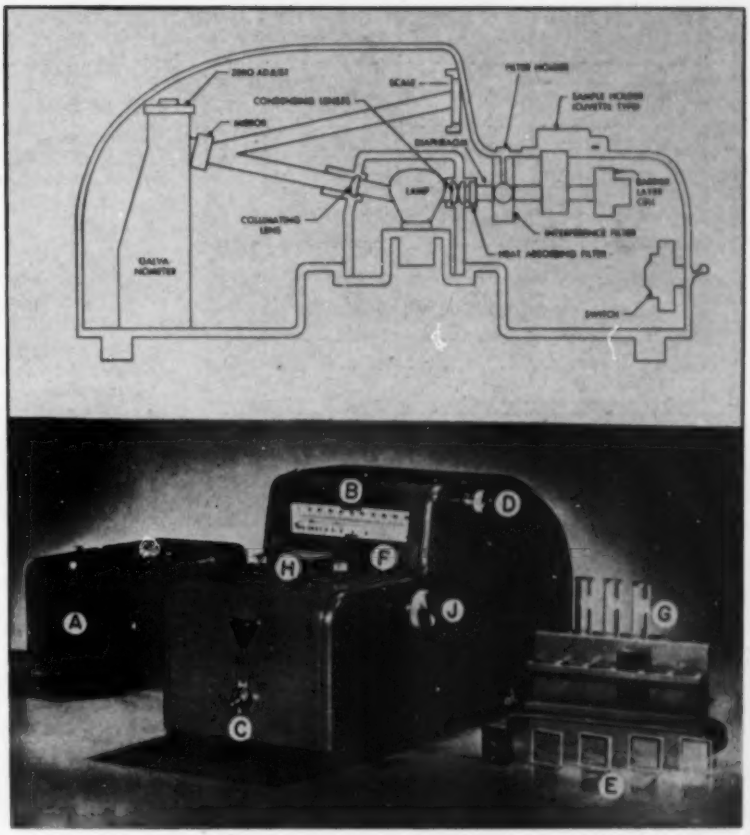

Fig. 1—The Bausch & Lomb monochromatic colorimeter: *A*—Transformer. *B*—Transmission scale. *C*—Toggle switch. *D*—Control knob. *E*—Interference filter. *F*—Filter channel. *G*—Test tube. *H*—Sample space. *J*—Adjustment knob.

Rapid Estimation of Mill Product Purity By Transparency Measurement

by S. C. Sun, H. M. Fisher, and R. E. Snow

RAPID colorimetric estimation of the amount of transparent minerals has been applied successfully to instream mill products at the cryolite flotation plant of the Pennsylvania Salt Mfg. Co., Natrona, Pa. Apparatus used was a Bausch & Lomb monochromatic colorimeter. The optical assembly of the colorimeter, shown in Fig. 1, passes light from a 6-v, 32-cp, prefocus incandescent lamp through two condensing lenses, a heat-absorbing filter, an aperture-control diaphragm, an interference filter, and a sample container. The light finally strikes a barrier-layer photocell and the output current of the photocell is measured by a galvanometer. The engraved index line of the collective lens, located between the lamp and the galvanometer, is imaged upon the transmission scale of the colorimeter by the galvanometer mirror. Reflected light from the galvanometer mirror, the position of which is determined by the output current of the photocell, enables reading of percent transmission throughout the mineral sample being tested.

The colorimeter, Fig. 1, was standardized as follows: 1—The colorimeter was connected to a Sola constant voltage transformer, *A*, of 6-v output operated from a 110-v ac supply. 2—Turning the toggle switch, *C*, illuminated the transmission scale, *B*, and the control knob, *D*, was adjusted with a blank in the optical system until the hairline on the scale read zero. 3—A No. 430 interference filter, *E*, was inserted into the filter channel, *F*. 4—A test tube, *G*, containing 7 cc of distilled water was pressed into the sample space, *H*, and the fine adjustment knob,

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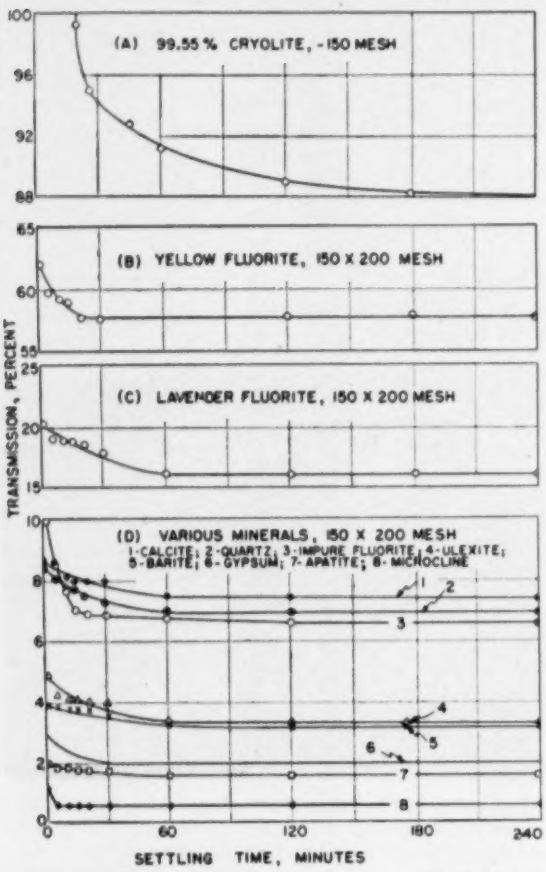
(A) 99.55 % CRYOLITE, -150 MESH
(B) YELLOW FLUORITE, 150 X 200 MESH
(C) LAVENDER FLUORITE, 150 X 200 MESH
(D) VARIOUS MINERALS, 150 X 200 MESH
1-CALCITE; 2-QUARTZ; 3-IMPURE FLUORITE; 4-ULEXITE; 5-BARITE; 6-GYPSUM; 7-APATITE; 8-MICROCLINE
TRANSMISSION, PERCENT
SETTLING TIME, MINUTES

Fig. 2—Transparency of various mineral sediments after different settling times.

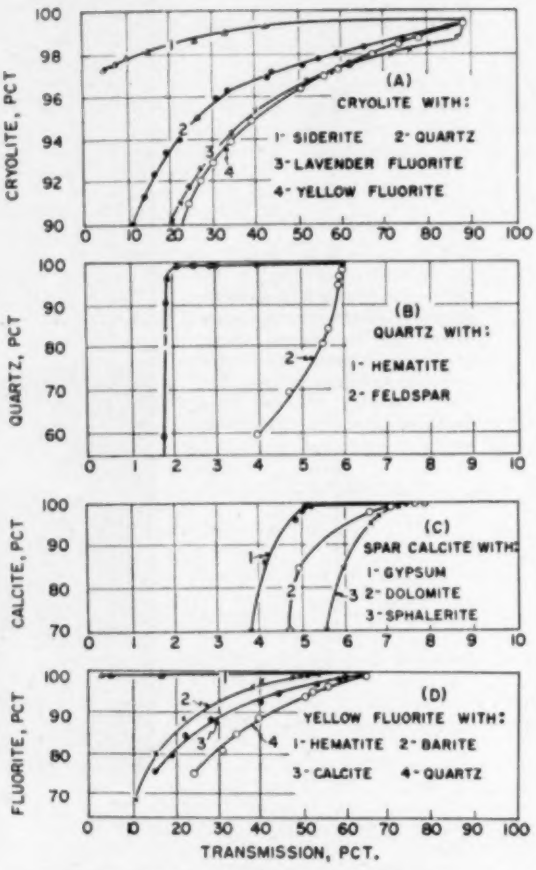

Fig. 3—Effect of mineralogical composition on transparency of mineral sediments. All minerals used —150 mesh.

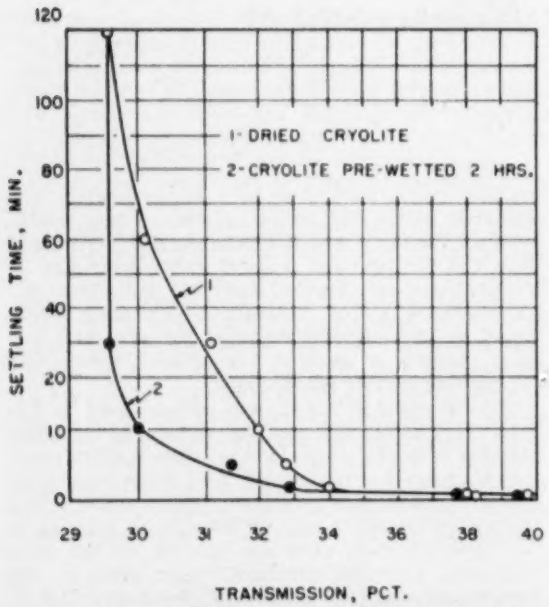

Fig. 4—The effect of settling time on transparency of —65 mesh cryolite sediments.

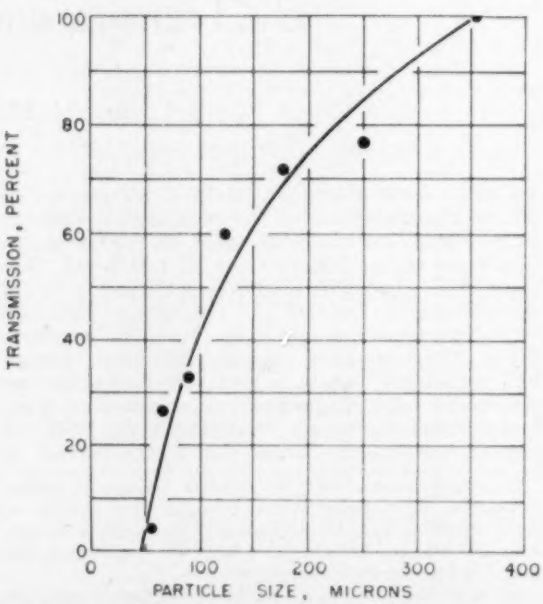

Fig. 5—The effect of particle size on the transparency of cryolite sediments.

J, turned until the hairline was set at a predetermined point of the transmission scale. 5—The test tube and then the filter were removed from the colorimeter.

The distilled water standard setting used for the highly transparent cryolite samples was arbitrarily chosen as 10, and for the less transparent minerals 100. A setting of 100 admitted too much light for measuring the cryolite samples, resulting in off-scale deflection.

The experimental procedure for measuring transparency of mineral sediments was carried out as follows: 1—A predetermined amount of sized mineral sample, usually 4 g or more, was weighed out and placed in a test tube of 1.2 cm OD to form a mineral column not less than 2.1 cm high. 2—Four cubic cm of distilled water were added to the test tube and shaken for 1 min; 3 cc. of distilled water were then added and shaken for 2 min. 3—The test tube containing this mineral pulp was inserted into the sample space of the standardized colorimeter, and the transmission scale reading was recorded at various time intervals until the reading became constant. Unless otherwise stated data presented here were taken after 4 hr settling.

Figs. 2-5 indicate that while the light source and the mineral container are kept constant, the transparency of mineral sediments is chiefly governed by: 1—mineralogical composition, 2—settling time, and 3—particle size of the sediment. Concerning point 1, Fig. 2 shows that the transparencies of individual mineral sediments differ appreciably; generally speaking, transparencies decrease in the order of cryolite, fluorite, calcite, quartz, impure fluorite, ulexite, gypsum, and microcline. This is because the absorption coefficient and/or the refractive index of these minerals increase in the same order. The absorption and reflection of light by a mineral increase respectively with an increase of the absorption coefficient and the refractive index[1] of the mineral. When light is sent through a column of mineral sediment, the incident light is partly absorbed and partly reflected and only the remainder is transmitted and measured. Fig. 3 shows that the transparency of a considerably transparent mineral sediment is gradually lowered when it is blended with increasing amounts of a less transparent mineral. This phenomenon becomes even more pronounced when the added mineral particles are opaque. Thus, under restrictive conditions, the purity of a transparent mineral can be estimated by means of transparency measurement.

Concerning point 2, Fig. 2 shows that the transparency of a mineral sediment decreases with settling time until a constant transmission is attained. A 2-hr settling time was sufficient to establish a constant transmission for all minerals tested, except that 4 hr were necessary for the −150 mesh cryolite. In contrast, Fig. 4 shows that the necessary settling time of −65 mesh cryolite is 2 hr. Furthermore, when the same cryolite sample is pre-wetted in distilled water and allowed to settle a second time, the necessary settling time is reduced to only ½ hr. The disadvantage of the long settling time required was eliminated by centrifuging the mineral pulp for 10 min at 2850 rpm and allowing the compacted sediment to stand for 5 min before transparency measurements were taken. The relation between transmission and settling time can be explained by the fact that the interstices of mineral sediment decrease gradually with an increase of set-

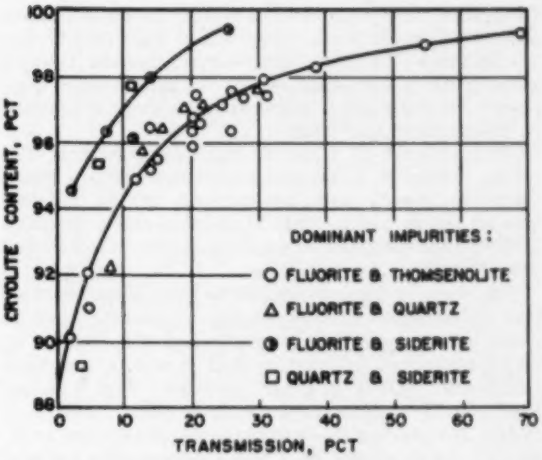

Fig. 6—Effect of the type of dominant impurities on the transparency of cryolite flotation concentrates. Note that the cryolite samples used were prepared from different ores and were all −150 mesh.

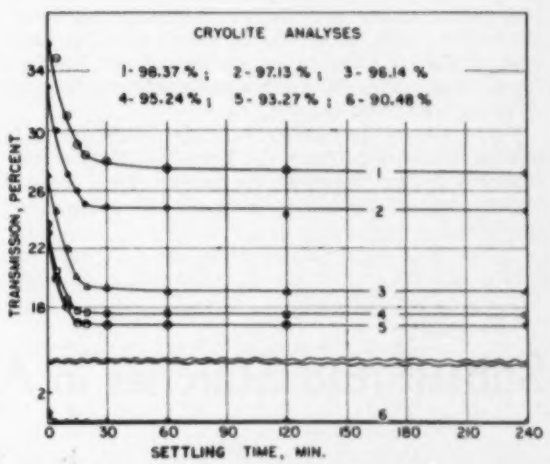

Fig. 7—Estimation of the grade of cryolite flotation concentrates. Note that all cryolite samples were prepared from the same ore and were −150 mesh.

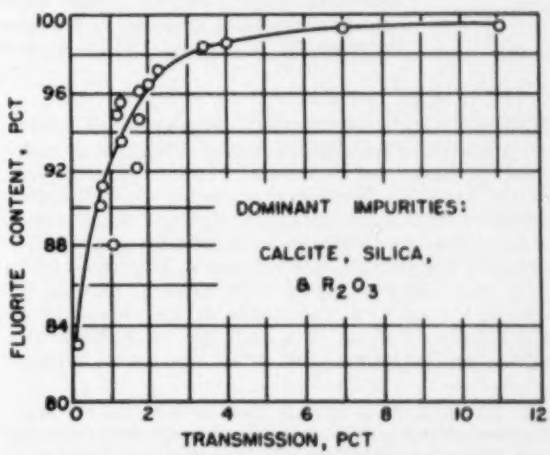

Fig. 8—Estimation of grade of fluorite flotation concentrates. Note that the fluorite samples were furnished by two different mills and were all −100 mesh.

tling time and eventually become constant. These interstitial voids filled with distilled water are highly transparent. The fact that some minerals require more settling time than others for establishing constant transmission is attributed to their difference in density and wettability.

With regard to point 3, Fig. 5 shows that the transparency of a mineral sediment, within certain limits, increases with an increase of the particle size of the mineral. This is because the interstices between the particles of a coarse sediment are larger than those of a fine sediment.

The data of Figs. 6-8 indicate that under restrictive conditions a monochromatic colorimeter can be employed for a quick estimation of the content of any transparent mineral in mill products, resulting in a better control of plant operation. Fig. 6 shows that siderite is more effective than other impurities tested in reducing the transparency of cryolite sediments. This implies that the transparency method is applicable only when the mineralogical composition of the dominant impurities of cryolite concentrates is pre-determined. Fig. 7 shows that when the impurities of cryolite samples are dominated by the same gangue minerals, the difference in cryolite content of the samples is revealed by the transparency method. It should be noted that the samples of Fig. 6 were prepared from four different types of cryolite ore, whereas all samples of Fig. 7 were derived from one ore.

Fig. 8 shows that under suitable conditions it is also possible to estimate the grade of fluorite concentrates by the transparency method. Figs. 6 and 8 indicate also that as now designed the colorimeter used in this investigation cannot give accurate measurements for samples containing less than 90 pct cryolite or fluorite because of their low transmission. However, this is not a serious drawback, as the acceptable grades of the flotation products of cryolite and acid-grade fluorite are respectively higher than 96.5 and 92 pct and are thus far above the lower limit of the colorimeter. Furthermore, this limitation can be partly eliminated by increasing the light intensity and the transmission scale of the colorimeter, reducing the diameter of the sample container, or both.

Summary

1—A transparency method is described for estimating the grade of cryolite and fluorite concentrates under restrictive conditions.

2—The colorimeter used in this investigation has been found useful in the estimation of the grade of concentrate of highly transparent minerals, but a colorimeter possessing greater light sensitivity would be necessary for estimation of grade of the concentrate of the less transparent minerals.

Acknowledgments

The writers wish to thank D. C. Spees of the Fluorspar Division, Minerva Oil Co., Eldorado, Ill., for providing the fluorite samples. They also wish to thank L. Goldenhar, J. F. Gall, D. R. Mitchell, A. E. Clement, and H. B. Charmbury for their active interest in this work.

Reference

[1] E. Hausmann and E. P. Slack: *Physics*, 2nd ed., p. 618. D. Van Nostrand Co., Inc., 1939.

Substituted Starches in Amine Flotation of Iron Ore

by C. S. Chang

Replacement of active groups in corn starch, as shown by results of the starch derivatives tested, impairs rather than improves the value of corn starch as a selective iron oxide depressant. Increased ability to depress iron oxides is generally accompanied by a parallel ability to depress quartz.

PEARL starch, a corn starch prepared with a minimum of alteration, is a good selective depressant for iron oxide minerals.[1] From what is known of the complex chemistry of corn starch, there is evidence that it consists of a mixture of saturated giant polymeric molecules, both straight and branch-chained, the constituents consisting of glucose units with hydroxyl radicals as active or polar groups. To add to the existing knowledge of the chemistry of the flotation process, it is desirable to ascertain the effects on the corn starch as an iron oxide depres-

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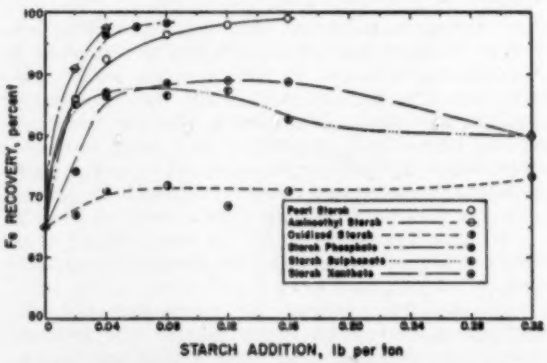


Fig. 1—Effect of starch addition on iron recovery. Laurylamine acetate addition at 0.26 lb per ton.

sant when some of the hydroxyl radicals are replaced by other active groups that are common to flotation reagents.

The ideal way to carry out this investigation would be to test reagents containing different active groups derived from corn starch. The preparation should be such that the reagents possess the same degree and location of substitution and are accompanied by little or no degradation of the starch molecules. This, of course, is almost impossible to realize, as it is difficult to control the degree and location of substitution as well as to prevent degradation of the starch molecule during preparation.

There are two general methods of changing the active group in starch. One is by direct conversion of the active group. The other consists of adding ether or ester groups, containing the desired radicals, to the starch molecule.

Several such substituted starches, derived from a whole corn starch, were prepared in experimental quantities by the Chemical Div., Corn Products Refining Co. Their effects as iron oxide depressants were tested on a wash-ore tailing, laurylamine acetate being used as a collector.

Ore Sample: The iron ore, consisting mainly of hematite, goethite, and quartz, was a wash-ore tailing obtained from the western Mesabi Range. It was

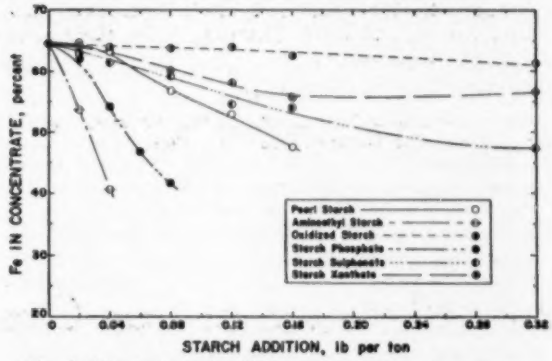


Fig. 2—Effect of starch addition on percent iron in concentrate. Laurylamine acetate addition at 0.26 lb per ton.

ground through 100 mesh, scrubbed with sulphuric acid, and thoroughly deslimed at approximately 20 microns. Flotation feed assayed 33.15 pct Fe.

Flotation: Flotation tests were made in a 50-g pneumatic type cell.[1] The feed was first conditioned for 2 min in 200 ml of solution containing the starch reagents. The collector, laurylamine acetate (99.9 pct pure), was then added and the pulp reconditioned for another 30 sec. The froth was removed until barren of minerals. Demineralized water with impurity less than 0.1 ppm of salts expressed as NaCl was used in all solution preparations. For details pertaining to the ore sample, the method of preparation, and the description of the flotation apparatus, readers are referred to a previous paper.[1]

Starch Reagents: Reactions involved in the preparations of the reagents are illustrated by equations given at the end of the description of each starch.

1—Pearl starch, a whole corn starch prepared with minimum alteration, is essentially insoluble in water at room temperature.

2—Aminoethyl starch, see below, is an ether derivative of corn starch containing, in the sample used, approximately one aminoethyl group ($-O-CH_2CH_2NH_2$) for each 10 glucose units. This material is almost insoluble in cold water.

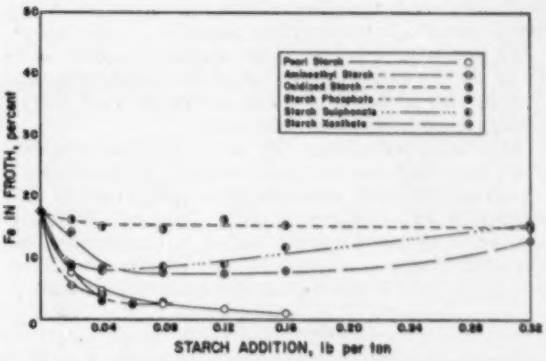
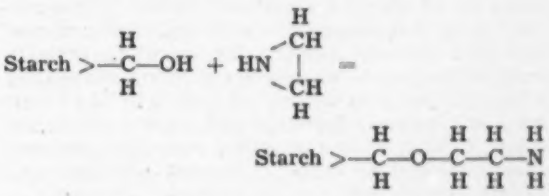
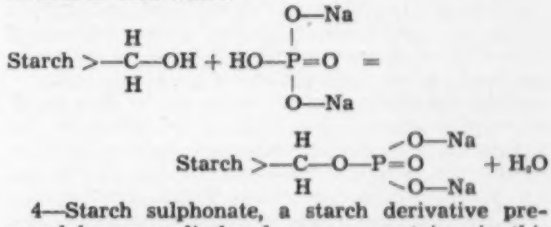


Fig. 3—Effect of starch addition on percent iron in froth. Laurylamine acetate addition at 0.26 lb per ton.

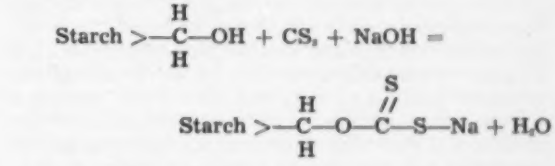


3—Starch phosphate, see below, is an ester derivative of corn starch with the phosphate in the ortho form ($-O-P(=O)(-O-Na)-O-Na$). The sample tested was made from a somewhat degraded starch and contained one ester group for approximately each 30 glucose units in the starch molecule. It is insoluble in cold water.



4—Starch sulphonate, a starch derivative prepared by an undisclosed process, contains, in this sample, approximately one sulphonic acid group on a side chain in each 25 glucose units. It also is insoluble in cold water.

5—Starch xanthate, derived from corn starch, contains a xanthate group ($-O-C(=S)-S-Na$). The sample used was partially degraded and had one xanthate group in each four glucose units. It is soluble in hot water.



6—Oxidized starch is prepared by treating corn starch with nitrogen dioxide. In the present sample, 35 pct of its terminal hydroxyls are converted to carboxyl groups ($-C(=O)-OH$). The treatment causes

considerable degradation of the starch molecule and the product is soluble in hot water.

To varying extents these starch reagents may have been degraded during preparation. Also the degree and location of substitution of their active groups is not necessarily the same.

Solutions containing 0.1 pct of these reagents were prepared for flotation addition. The solutions of water-insoluble reagents were prepared by digestion in an autoclave at 120°C for 1 hr. With the exception of pearl starch, which is a common unmodified commercial starch, the reagents used in this study are experimental laboratory products.

Experimental Results

In the presence of a starch depressant, the optimum results for the particular ore sample used were obtained with 0.26 lb laurylamine acetate per short ton of ore.[1] An additional frother is unnecessary, as at this concentration the collector possessed sufficient frothing power. Therefore all flotation tests were made at this same collector addition and the starch addition was varied from 0 to 0.32 lb per ton. The ore was floated at the natural pH of the pulp, 6.5±0.4, since regulating to higher or lower than the natural value in general produced less satisfactory results.

Flotation results are presented in Figs. 1, 2, and 3, which show respectively the iron recovery, the percent iron in the concentrate, and the percent iron in the froth plotted against the starch addition. From these graphs it can be seen that replacement of the active groups in corn starch causes variation in its effectiveness as an iron oxide depressant.

It should be pointed out that the mere addition of 0.26 lb of collector per ton can produce a concentrate assaying about 65 pct Fe with a recovery of about 65 pct, i.e., 35 pct of the iron floats in the silica froth. An ideal selective iron oxide depressant should increase the recovery to almost 100 pct without lowering the iron content of the concentrate.

Oxidized starch has no value as an iron oxide depressant, since it has little or no effect on the separation. Aminoethyl starch and starch phosphate satisfy the recovery requirement, Fig. 1, but the iron content of the concentrate, Fig. 2, declines rapidly with increased addition. This indicates that these two starches, particularly the aminoethyl starch, have a strong tendency to depress not only the iron oxide minerals but also the quartz. This is in agreement with the finding of Cooke and coworkers.[2] Further, the addition of 0.06, 0.10, or 0.20 lb per ton respectively of aminoethyl starch, starch phosphate, and pearl starch depresses all minerals. Although addition of starch sulphonate or starch xanthate does not seriously lower the grade of the iron concentrates neither does it raise the iron recovery to even 90 pct. With increased pearl starch addition the iron recovery rises to almost 100 pct. The increase in recovery is not as rapid as in the case of aminoethyl starch or starch phosphate, but it is not accompanied by the rapid decline of the grade of the iron concentrate. For these reasons a product assaying 60 pct Fe can be obtained with the use of pearl starch at a recovery as high as approximately 95 pct.

Discussion

To become effective as well as selective a depressant must be adsorbed liberally on the mineral to be affected and sparsely, if at all, on the mineral to be floated. This is confirmed by results of an adsorption study made by Schulz and Cooke.[3] Pearl starch coats Brazilian hematite better than it coats quartz. On the other hand, the non-selective aminoethyl starch is adsorbed extensively on both Brazilian hematite and quartz. Mesabi hematite, however, was reported to adsorb less starch per unit of surface than quartz. It must be remembered that the Mesabi hematite used possesses a large internal surface. This is exhibited by the great difference between the air-permeability surface (2060 cm^2 per g) and the krypton-adsorption surface (128,600 cm^2 per g). Since the size of the liquid krypton molecule is much smaller than that of the giant starch molecule, it is possible that the surface accessible to krypton adsorption may be inaccessible to starch adsorption. For this reason the starch adsorption data for Mesabi hematite, which is based on the krypton-adsorption surface, could be several orders of magnitude lower than the true values.

It was also reported by Schulz and Cooke[3] that the addition of Gum 3502 did not affect the adsorption of laurylamine acetate on hematite. This contradicts the general belief that the function of a depressant is to prevent or minimize the adsorption of collector on the mineral surface. Nevertheless it is not difficult to conceive that starch, being of negative charge, is adsorbed simultaneously with the positively charged amine collector by the hematite surface. The fact that the starch molecules are much larger and longer than the amine ion or molecule may very well obscure the hydrophobic characteristics of the collector.

Conclusions

Replacement of active groups in corn starch causes varying effectiveness as an iron oxide depressant in amine flotation of iron ore.

The replacement as shown by the results of the starch derivatives tested impairs rather than improves the value of corn starch as a selective iron oxide depressant.

Increased ability to depress iron oxides is generally accompanied by a parallel ability to depress quartz.

The following starches are listed in the order of decreasing ability to depress iron oxides as well as quartz:

1—aminoethyl starch, 2—starch phosphate, 3—pearl starch, 4—starch sulphonate, 5—starch xanthate, 6—oxidized starch.

Acknowledgments

The author is indebted to Harry Gehman, Assistant Director of Research, Corn Products Refining Co., for his generous contribution, particularly in making available the various starch reagents tested, to V. E. Bye and his associates of the University of Minnesota for conducting the analytical work; and to Strathmore R. B. Cooke of the same institution for his invaluable assistance in preparing this paper.

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Adsorption of a Mercaptan on Zinc Minerals

by A. M. Gaudin and D. L. Harris

Observations were made of the distribution of mercaptan containing S_{35} between aqueous solution and mineral and between aqueous solution and the gaseous phase. Although equilibrium may not have been attained, adsorption of the reagent was shown to occur readily from air or aqueous solution on sphalerite, zincite, and willemite and to correspond to flotation. Adsorption on quartz did not similarly occur.

THE following results, presented here in condensed form,[1] were obtained in a preliminary study of the adsorption of n-hexane thiol, hexyl mercaptan, on sphalerite, zincite, willemite, and quartz, from aqueous solution and from a gas. Interest in this subject was aroused by a Belgian report[2] of effective use of hexyl mercaptan for flotation collection of oxidized zinc minerals. The relatively low boiling point, 149°C, of the mercaptan[3] suggested the desirability of extending the usual measurements of partition of collector between aqueous solution and gas and between gas and mineral. It is believed that this paper presents the first measurements of this type on a flotation system. Attempts were made to carry out the measurements at equilibrium, but as the work progressed it became increasingly doubtful that this desirable condition had been achieved.

To control composition and extent of the gas phase, the apparatus was a wholly-enclosed thermally-controlled glass system. Because of these constraints and the desirability of dealing with pure minerals, a scale of operations was chosen in which a few grams of deslimed mineral were used in each test. It was also necessary to choose a particularly sensitive method for mercaptan analysis, and in fact a method that would permit the experimenters to follow the approach to equilibrium. For these reasons mercaptan marked by radiosulphur 35 was used. An analysis was made for the radiosulphur by a modification of the method of Gaudin and Carr.[4]

Coarsely-crystallized sphalerite was handpicked, stage-crushed in the dry state, wet-screened on a 200-mesh sieve, and deslimed in water at about 5 microns. Further treatment consisted of a wash in dilute aqueous hydrogen peroxide, drying, removal of the dark-colored fraction in a Frantz magnetic separator, washing in very dilute hydrochloric acid, repeated washing in distilled and conductivity water, and drying. The last washings showed a conductivity equivalent to a few ppm NaCl, that is, much more than would be provided, theoretically, by a saturated ZnS solution. The material was stored dry in sealed bottles. Analyses were as follows: Zn, 62.3 pct; Fe, 0.43 pct; Cd, 0.44 pct; S, 31.2 pct; Mn, 0.001 pct. The specific surface (BET method) was 2000 cm²/g.

Zincite from Franklin furnace of the New Jersey Zinc Co. was hand-picked, dry-crushed, wet-screened at 100 mesh, and deslimed at about 10 microns. After drying, the associated zinc, manganese, calcium, and silicate minerals were removed in a Frantz magnetic separator. The purified zincite was washed in distilled water and conductivity water to a conductance of less than 2 ppm equivalent NaCl, dried, and stored. Analyses were as follows: Zn, 75.1 pct; Fe, 0.9 pct; Mn, 2.78 pct. The specific surface (BET method) was 1740 cm²/g.

Willemite, also from Franklin furnace, was purified similarly. Analyses were as follows: Zn, 52.5 pct; Fe, 0.12 pct; SiO_2, 27.3 pct; loss on ignition, 0.13 pct. The specific surface was 1760 cm²/g.

Conductivity water (double-distilled) and demineralized-distilled water were used in most of the tests. The specific resistance was not less than 600,000 ohms, and usually above 1,000,000.

Radiosulphur-marked hexyl mercaptan (1-hexane thiol) was synthesized by Tracerlab, Inc., Boston. Two lots were secured several months apart. The last lot, consisting of about 0.5 g of the mercaptan, had a total activity of about 10 millicuries. Tracerlab Co. guaranteed only the activity; hence a quasi-vapor pressure determination (based upon an S_{35} analysis) of the mercaptan was made. The calculated value, 4.2 mm of mercury at 25.5° C, has been compared with that of a sample of *Highest Purity* 1-hexane thiol from Fisher Scientific Co. The latter had a vapor pressure of 4.5 mm of mercury at 2.5°C.

Analytical Procedures

The sample containing radiosulphur-marked mercaptan was oxidized to convert the mercaptan sulphur to sulphate, carrier barium sulphate being added to provide a suitable quantity of total barium sulphate in a filter cake. The precipitate was filtered and dried, and counting was carried out either in a streaming-gas (Q-gas) counter for high sensitivity or with an end-window G-M counter for convenience. The oxidized and precipitated mercaptan gave a radioactive count of 65 counts per minute per microgram in the end-window Geiger-Mueller counter and 1100 counts per minute per microgram in a Q-gas counter.

For standardization of the mercaptan solution, 15 replicate analyses were made. The average deviation per measurement was about 1600 cpm in 65,000 cpm, the probable error in the mean being 275 cpm. It

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might therefore be anticipated that a single measurement might be as much as 2 to 3 pct in error. The radiochemical technique is described in detail in the thesis by Dwight L. Harris.[1]

Proportionality of activity measured in a Q-gas flow counter to the amount of mercaptan taken was satisfactory.

Surface area measurements were made in a BET apparatus with Krypton at the temperature of boiling nitrogen.[5]

Experiments in which the partition of mercaptan between aqueous solution and mineral was sought were carried out in a glass vessel of about 200-ml capacity similar to a separatory funnel but with a side arm provided with a fritted glass filter and a stopcock. About 5 g of mineral were placed in this cell, washed with very dilute hydrochloric acid, and washed repeatedly with double-distilled water. Then the vessel was nearly filled with conductivity water and the desired agents were introduced through the stopcock by means of a needle-stem microburette; the mercaptan was added in solution in isopropyl alcohol, as a single addition from a 0.10-ml pipette. The cell was mounted on a rack in a constant-temperature bath and rotated for the selected duration of the experiment at 20 rpm. At the end of the experiment the liquor was drawn through the fritted glass filter and the solution and solid were analyzed for radiosulphur.

This description of the principal test procedure makes it clear that equilibrium was approached from below, that is, that the solid at no time had adsorbed an excess of agent over the equilibrium amount. To approach equilibrium *from above* a few desorption experiments were conducted by exposing agent-covered mineral to the leaching action of a more dilute solution of the agent, or by plain water.

Experiments for the purpose of evaluating the adsorption of mercaptan vapor on dry minerals were semi-quantitative only. Weighed samples of mineral in fritted glass containers and a small amount of active mercaptan in an open cup were placed in a covered jar. The quantity measured was the activity acquired by the mineral (determined by leaching the agent) after the passing of time. Some of the activated mineral was subjected to a moderate vacuum before analysis.

Distribution of mercaptan between aqueous solution and gas phase was obtained for a number of alkaline solutions by two methods. One method was by calculation on the basis of the ionization constant of hexyl mercaptan as measured by Yabroff[7] (1.9×10^{-11}); the measured distribution in neutral solution; the pH of the liquor as measured by the present

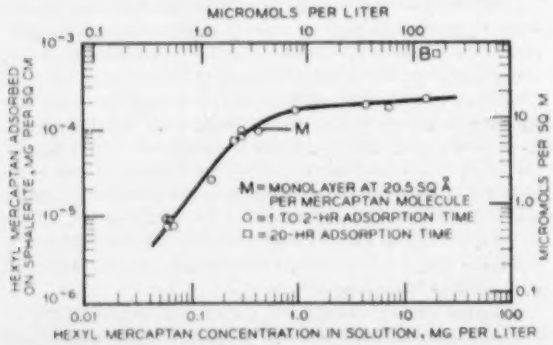

Fig. 1—Mercaptan concentration in solution vs the amount on sphalerite.

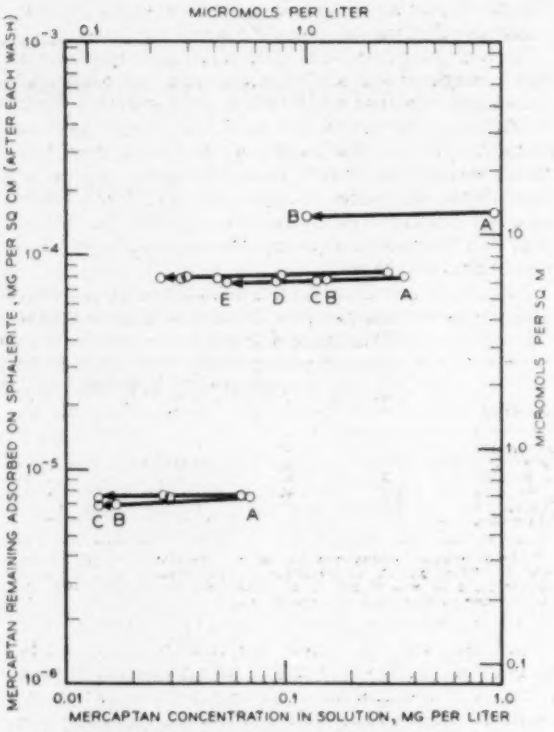

Fig. 2—Desorption. Mercaptan concentration in solution vs amount on mineral. Desorption time equals 1 hr for each succeeding leach.

experiments in a glass-electrode pH meter; the volumes of gas and aqueous solution; and Henry's law. The second method was directly experimental by radiosulphur assay for both gas and liquid phase.

Results from Adsorption Experiments

Sphalerite: Fig. 1 shows the distribution of hexyl mercaptan between sphalerite and aqueous solution (substantially neutral), all measurements representing attempted approaches to equilibrium from below. The hexyl mercaptan analyses were all radiometric, that is, it was implicitly assumed that no radioactive sulphur compounds other than mercaptan occurred in the reagent introduced in the cell or were produced by chemical reaction.

The change of slope at *M* in the region corresponding to monolayer coverage is noteworthy. It is also interesting to note the large increase in activity of the coated mineral on prolonged contact in concentrated solution (point *B*). This suggests that equilibrium was not attained or that side reactions occurred.

Two additional series of experiments were also conducted in the effort to approach equilibrium from above. In one of these series certain of the coated minerals from the experiments reported in Fig. 1 were leached repeatedly with distilled or conductivity water for 1-hr periods and the leaches analyzed. Data for the 5 experiments made are presented in Fig. 2. Successive washes produced increasingly dilute filtrates, as may be seen from the succession of points bearing consecutive letters of the alphabet, but these leachings removed so little S_m from the coated mineral as to affect its retention of S_m hardly at all. If the data of Fig. 1 had represented equilibrium conditions, desorption data (such as those of

Fig. 2) should have formed a curve identical to Fig. 1 instead of being widely different.

In the second series of desorption experiments much longer periods of equilibration were applied (18 to 50 hr instead of ½ to 2 hr). The data, shown in Fig. 3, differ from those of Fig. 2 in that the assay of the terminal wash water, in at least two cases, was higher than that of the adsorption solution. When the data of Figs. 1, 2, and 3 are taken together, the conclusion must be reached that Fig. 1 does not represent equilibrium conditions or that side reactions occur.

Table I. Adsorption and Desorption of Hexyl Mercaptan on Zincite from Aqueous Solution*

Operation	Time, Hr	Mercaptan Distribution		
		Solution Mg Per Liter	Adsorbed Mg Per Sq Cm	Percentage on Mineral
Adsorption	1.0	0.193	9.0×10^{-6}	98.8
Desorption	1.0	0.155	8.73×10^{-6}	94.3
Desorption	0.5	0.149	8.5×10^{-6}	91.8
Desorption	0.5	0.142	8.3×10^{-6}	89.5
Desorption	0.5	0.133	8.1×10^{-6}	87.5
Desorption	0.5	0.105	7.95×10^{-6}	85.8

* The mercaptan added was 1.0 mg for the test. The pH of the tests was 7.5 to 8.0; the temperature was 26°C; the amount of zincite surface area was 10,800 sq cm; the volume of water was 164 ml for each sorption and desorption test.

One test was conducted to ascertain whether adsorbed radioactive mercaptan, about one monolayer thick, would exchange with inactive mercaptan in solution. This test showed that about 0.8 pct of the radiosulphur was emitted in 1½ hr. It may be concluded that under the experimental conditions used the rate of exchange is extremely slow, that the equilibrium concentration of true mercaptan in solution is extremely minute, and/or that side reactions interfere with exchange.

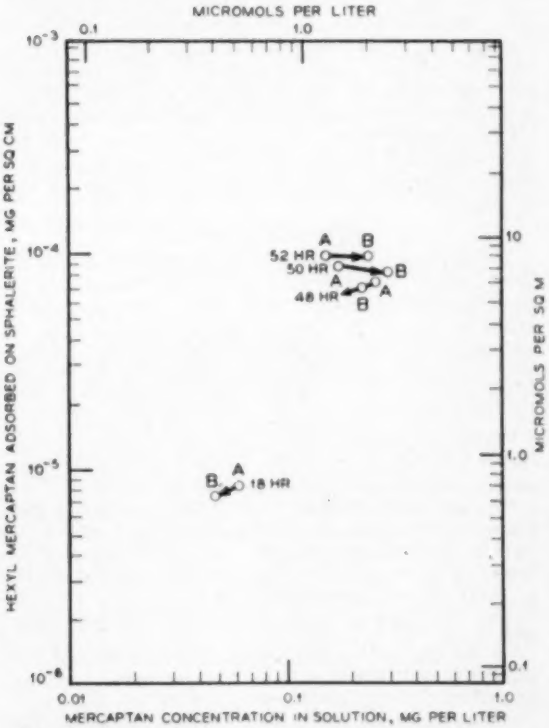

Fig. 3—Desorption. Mercaptan concentration in solution vs amount on sphalerite. Long desorption periods.

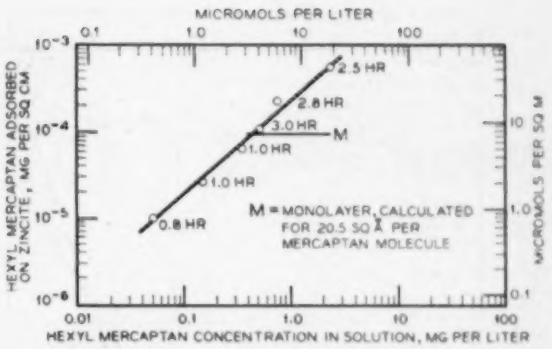
MICROMOLS PER LITER
HEXYL MERCAPTAN ADSORBED ON ZINCITE, MG PER SQ CM
MICROMOLS PER SQ M
2.5 HR
2.8 HR
3.0 HR
1.0 HR
1.0 HR
0.8 HR
M
M = MONOLAYER, CALCULATED FOR 20.5 SQ Å PER MERCAPTAN MOLECULE
HEXYL MERCAPTAN CONCENTRATION IN SOLUTION, MG PER LITER

Fig. 4—Mercaptan concentration in solution vs the amount on zincite.

Several tests were made in alkaline circuits ranging from pH 7.5 to pH 12. The data suggest that pH within this range is not an important variable. An increase in temperature up to 40°C also had no significant effect.

Zincite and Willemite: Fig. 4 shows the data obtained on the system zincite-water for mercaptan distribution (equilibrium approached from below). The data show almost linear dependence of the amount adsorbed on the concentration of the mercaptan, with no saturation in sight when a monolayer is reached.

A single adsorption-desorption test was made to determine whether equilibrium was attained. The results indicate, see Table I, that adsorbed mercaptan is removed with difficulty and that equilibrium probably was not attained.

Data reporting the mercaptan distribution in the water-willemite system are presented in Table II.

Table II. Adsorption of Hexyl Mercaptan from Aqueous Solution Onto Willemite*

Test No.	Mercaptan Added in Cell	Agitation Time, Hr	Mercaptan Analyses		Mercaptan Abstracted by Solid Pct of Total
			Solution Concentration, Mg Per Liter	Abstracted by Mineral Mg Per Sq Cm	
1	0.1	2	0.133	0.82×10^{-6}	78.2
2	0.1	1.5	0.156	0.78×10^{-6}	74.4
3	1.0	2	1.66	7.66×10^{-6}	72.7
4**	1.0	2.1	2.64	8.17×10^{-6}	77.8
5	2.0	2	2.58	16.5×10^{-6}	78.2
6	10.0	3.7	21.8	67.5×10^{-6}	64.3

* Temperature = 26°C; pH = 7.5 approximate; solution volume = 164 ml; mineral sample = 5.4 g; total mineral surface area 9500 sq cm.

** Test 4 was made with a gas phase of 80 ml and a liquid phase of 84 ml. The mercaptan in the gas phase represented only 0.66 pct of the total added to the cell.

This table shows that mercaptan is readily adsorbed and also that the solution concentration represents a larger proportion of the agent added to the cell than in the cases of zincite or sphalerite.

Indirect measurements (the analyses of a gas phase in equilibrium with the solution and mineral phase, and a comparison with distributions measured for hexyl mercaptan in solution and gas phases) suggested that most of the sulphur (the basis of the mercaptan analysis) in the filtrate was not present as hexyl mercaptan.

Quartz and Pyrex Glass: Tests were made to ascertain whether quartz and pyrex powders adsorb mercaptan from neutral aqueous solution. They showed no measurable adsorption.

Adsorption From the Gas Phase: Semi-quantitative tests are reported in Table III. Mercaptan

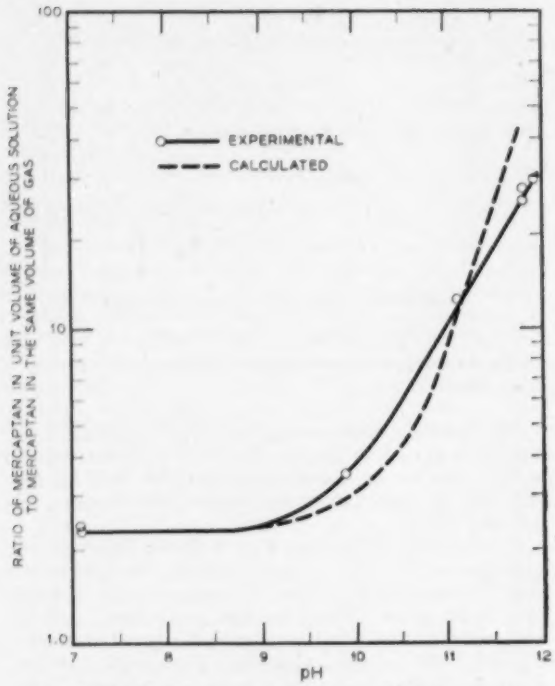

Fig. 5—Distribution of mercaptan between fluid phases as a function of alkalinity.

vapor at room temperature, 28° to 34°C, in an air atmosphere was adsorbed on dry samples of mineral and the solids were analyzed. The results, tests 1 to 5, showed that mercaptan vapor is readily taken up by sphalerite. Test 5 also indicates that this amount (equivalent to several monolayers) is strongly adherent; after evacuation for 7.5 hr the amount of mercaptan retained by the mineral is approximately the same.

Table III. Adsorption of Hexyl Mercaptan Vapor on Dry Mineral*

Mineral	Test No.	Time, Days	Mercaptan Adsorbed, Mg Per Sq Cm
Sphalerite	1	4	2.54 X10⁻⁴
	2**	4	2.49 X10⁻⁴
	3	4	4.5 X10⁻⁴
	4	7	3.2 X10⁻⁴
	5†	7	2.8 X10⁻⁴
Monolayer at 22.5 A²/RSH molecule =			0.87 X10⁻⁴
Zincite	6	4	6.5 X10⁻⁴
	7	7	14.5 X10⁻⁴
	8†	7	2.8 X10⁻⁴
Willemite	9	4	4.7 X10⁻⁴
	10	7	3.1 X10⁻⁴
Quartz	11	7	0.19 X10⁻⁴
	12†	7	0.07 X10⁻⁴

* Conditions were identical for Tests 1 and 2, identical for Tests 4, 5, 7, 8, 10, 11, and 12 and identical for Tests 3, 6, and 9.
** Pulped in water and 3.28 pct of total mercaptan removed in the water, and 0.7 pct of total mercaptan removed on a fine fritted glass filter.
† Evacuated 7.5 hr before leaching.

Mercaptan is readily adsorbed also on dry zincite. The amount taken up in 7 days reaches the equivalent of 16 monolayers (test 7). Evacuation of a coated sample reduces the adsorption to about three monolayers, an amount equivalent to that retained by sphalerite after evacuation (test 8).

Two tests (9 and 10) are reported for the adsorption of mercaptan vapor on willemite. The amount of mercaptan taken up is comparable to that on sphalerite, about three monolayers in 4 to 7 days. For comparison with a nonreactive mineral, results are presented for adsorption of mercaptan vapor on quartz. Tests 11 and 12 show that the quartz does not effectively take up mercaptan.

Experiments of the same general type, refined to become truly quantitative, should open a large new field for understanding of flotation mechanism.

The theoretical method of evaluating the quantity of mercaptan in the gas phase in equilibrium with aqueous solutions of various basic pH values was based on several quantities, i.e., the amount of mercaptan added to the closed system, the concentration at the respective pH values, the distribution or mercaptan between gas and aqueous solution at a neutral pH, the ionization constant, and the application of Henry's law. Qualitative accord is noted between calculated values and measured values in Fig. 5.

Qualitative flotation and agglomeration tests were made for the zinc minerals, sphalerite, zincite, and willemite and for quartz powder as a comparison. In those partition tests in which a gas phase occurred together with the solution and mineral phases, agglomeration was readily noted for the zinc minerals after adsorption of mercaptan corresponding to less than monolayer coverage. Qualitative flotation tests in a test tube were also made with the application of vacuum to indicate flotation of the zinc minerals. These tests showed that adsorption of the mercaptan from the vapor phase prior to flotation testing was effective in causing flotation. On the other hand, quartz powder was not induced to float, or agglomerate, under similar conditions after having been exposed to mercaptan in the vapor form and/or in aqueous solution.

Summary

Adsorption of hexyl mercaptan on sphalerite, zincite, and willemite was shown to occur readily from water or from air but was shown to be absent for quartz. Qualitative flotation tests proved that flotation of the minerals occurred even when the amount taken up was equivalent to less than a monolayer. However, several effects are noted which suggest that equilibrium conditions have not been obtained in the adsorption and desorption tests in aqueous media, or that the mercaptan was impure.

Acknowledgements

The authors wish to thank Professors J. Th. G. Overbeek, P. L. de Bruyn, and D. W. Fuerstenau for their unstinting help. They also express appreciation to the U. S. Atomic Energy Commission for making this research possible and to the New Jersey Zinc Co. for supplying mineral products used in the research.

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aime NEWS

AIME FALL MEETING PROGRAM RANGES FROM COAST TO COAST

San Francisco

Minerals Beneficiation Div. meeting follows the American Mining Congress in San Francisco, on September 24. Registration will take place all during the week of the AMC gathering, and also on the day of the MBD meeting. Several outstanding papers are slated for presentation. Sessions will be held both Friday morning and afternoon, and meeting as well as luncheon will be at the Fairmont Hotel. The program appears on page 931.

Lake Placid

The Industrial Minerals Div. Fall Meeting at Lake Placid, October 5 to 9, promises much in the way of sports, technical sessions, and fellowship. Provisions have been made for entertainment of the ladies while the menfolk are wrapped up with technical matters. Headquarters will be the Whiteface Inn. The final day of the meeting, Saturday, will be devoted to field trips to outstanding mining operations of the Adirondack area.

Pittsburgh

Plans for the Annual American Society of Mechanical Engineers and American Institute of Mining and Metallurgical Engineers Joint Fuel Conference are solidifying. Program details are well mapped out for the meeting, scheduled for October 28 and 29, Pittsburgh. ASME is responsible for the technical sessions this year, with T. E. Purcell acting as General Chairman of the Conference Committee. The program appears on page 930.

Salt Lake City

Registration for the Rocky Mountain Industrial Minerals Conference at Salt Lake City starts October 28, with the meeting scheduled for October 29 and 30. The dinner dance is scheduled for Saturday evening at the Newhouse Hotel. Other features of the conference will be a list of outstanding technical papers and a chance to see two top football teams in action when the University of Utah and the University of Idaho clash in a great grid classic.

Joint Fuels Conference Program Almost Finalized

Program arrangements for the Joint Fuels Conference of the ASME and the AIME, October 28 and 29, William Penn Hotel, Pittsburgh, are set.

Right now, authors of specific papers for the sessions are busily rounding their productions into final shape. T. E. Purcell is general chairman of the Conference Committee. E. C. Payne is chairman of the Technical Events Committee.

THURSDAY, OCTOBER 28

Morning

Co-Chairmen—Paul D. Oesterle, Dravo Corp., Pittsburgh; **Carroll F. Hardy,** Appalachian Coal Inc., Cincinnati.

1. **Small and Medium Size Applications of the Cyclone Furnace**
   by W. I. Collins, Babcock & Wilcox Co., Pittsburgh.
2. **Travelling Grate Application Experience with Strong Coking Coals**
   by J. M. MacLachlan, Pittsburgh Consolidation Coal Co., Library, Pa.

Afternoon

Co-Chairmen—C. H. Sawyer, Eastern Gas & Fuel Associates, Pittsburgh; and **C. L. Potter,** Jones & Laughlin Steel Corp., Pittsburgh.

1. **Progress Report: Bureau of Mines Estimate of Coking Coal Reserves**
   by J. J. Dowd, U. S. Bureau of Mines, Pittsburgh.
2. **Coking Properties of Pittsburgh District Coals**
   by F. W. Smith, U. S. Bureau of Mines, Pittsburgh.
3. **Selection of Coals for Coking**
   by A. H. Brisse and J. H. Wells, both of U. S. Steel Corp.

FRIDAY, OCTOBER 29

Morning

Co-Chairmen—T. S. Spicer, Pennsylvania State University, and **Harry L. Washburn,** Pittsburgh Consolidation Coal Co., Library, Pa.

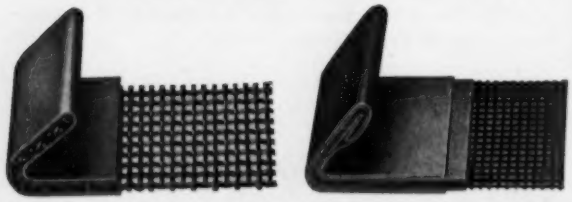
1. **Air Pollution Problems with Heat Drying of Fine Coal**
   by C. W. Gordon, Combustion Engineering Inc., Chicago.
2. **Problems Encountered with Industrial Waste Water**
   by H. F. Hebley, research consultant, Pittsburgh Consolidation Coal Co., Pittsburgh.

Afternoon

Symposium: The Operation of Continuous Mining Machines in the Tri-State Area.

Several papers are scheduled giving operating experience with various makes of equipment, used under variety of conditions in Ohio, Pennsylvania, and West Virginia.

Tyler Screen Sections for All Makes of Screening Machines!



Screen sections of Tyler Woven Wire are fabricated for all makes of vibrating screens in any mesh or metal. They are made up with hook-strip or bent-edge construction to suit the machine on which they are to be used.

Tyler rugged, accurately-applied hook-strips make possible stretching and maintaining the screens at drum-head tension, which is essential for successful screening and long screen life.

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Utah Section Members Discuss Meeting with Governor Lee

Members of the Utah Section, sponsors of the Rocky Mountain Industrial Minerals Conference, October 29 and 30, visit with the Governor of Utah to discuss details of the meeting program. Governor J. Bracken Lee is seated at the desk. Standing from left to right are Roger V. Pierce, Jack M. Ehrhorn, R. E. O'Brien, and W. F. Rappold.

Lake Placid Fall Meeting

WEDNESDAY, OCTOBER 6

Technical Session

Morning

1. **Geology of the Adirondacks**
   by Matt S. Walton, Jr.
2. **The Mineral Industries of the Adirondacks**
   by John A. Graham
3. **Geological Control of Adirondack Mineral Deposits**
   by A. E. J. Engle

Afternoon

1. **Anorthosite as an Industrial Mineral**
   by J. G. Broughton
2. **Talc Operations of International Talc Co.**
   by F. G. Kuehl and Roger Miller
3. **Magnetic Anomalies and Geophysical Prospecting in the Adirondacks**
   by LeRoy Scharon
4. **Genesis of Titaniferous Magnetites**
   by J. L. Gillson

Social Hour

Evening

Games before and after dinner.

THURSDAY, OCTOBER 7

Technical Session

Morning

1. **Wollastonite and Diopside, New Industrial Minerals**
   by Raymond Ladoo
2. **Commercial Colored Slates of New York and Vermont**
   by D. M. Larrabee
3. **Geochemistry and Importance of Saratoga Mineral Waters**
   by Lester W. Strock
4. **Quality Control in the Manufacture of Extender Pigments**
   by Charles H. Pratt

Afternoon

Field Trip

Social Hour

Evening

Film on Northern New York following dinner. Swimming in heated pool.

FRIDAY, OCTOBER 8

Technical Session

Morning

1. **Industrial Minerals of the Ottawa Valley**
   by N. B. Davis
2. **Gypsum Deposits at Dutch Settlement, N. S.**
   by C. Olivier Campbell

Afternoon

Social Events and Sports

Prize competition in various sports and noncompetitive games and activities.

Social Hour

Evening

Farewell Banquet

SATURDAY, OCTOBER 9

Full day of Field trips

Ladies' Program

WEDNESDAY, OCTOBER 6

10:00 am

Coffee Hour

Afternoon

Bingo, Bridge, Canasta (Prizes)

THURSDAY, OCTOBER 7

Morning

Shopping, sight-seeing around Lake Placid

Afternoon

Whiteface Memorial Highway bus trip to Tower. Side visit to Santa Claus Village

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MBD San Francisco Fall Meeting

FRIDAY, SEPTEMBER 24

Technical Session

Morning

1. **Sampling and Assaying Tungsten Ores at Getchell**
   by Keith Kunze and Roy Nojima
2. **Silver Bell Concentrator**
   by Norman Weiss
3. **Ring Problems in Rotary Kilns**
   by S. J. McCarroll
4. **Instrumentation of a Cement Kiln**
   by M. C. Sutton

12:30

Luncheon, Venetian Room, Fairmont Hotel

Afternoon

1. **Molybdenite Recovery at Morenci**
   by J. E. Papin
2. **Flow of Solids in Bulk Handling Systems**
   by Andrew W. Jenicke
3. **The Liquid-Solid Cyclone as a Classifier in the Closed-Circuit Grinding of Concentrates**
   by F. M. Lewis and E. C. Johnson

Around the Sections

• Second Annual Meeting of the **Lima, Peru Section** was held at the Lima Country Club. Cocktails, dinner, and dancing occupied members of the section until the small hours of the morning. Carl W. Westphal was reelected Chairman of the group for the coming year; Walter E. King was voted Secretary-Treasurer; and Alberto E. Brazzini was elected Assistant Treasurer. Ernesto A. Baertl was elected Chairman-Elect and will serve as chairman for the year starting June 1955. Arthur C. Hall was named alternate Section Delegate. Alfonso Ballon was elected Chairman of the Program Committee and Will G. Alexander, Chairman of the Membership Committee. Also serving on the Membership Committee are Mario Samame Boggio, Hernando Labarthe, and Everett H. Graff.

• **The color motion picture *Flamefoil Canvas* is again available. The film clearly illustrates the safety and serviceability features of fire, mildew, and water resistant canvas. The film is highly informative without being too detailed or technical, and may thus be used for a general audience showing. The movie is sponsored by the Philadelphia Textile Finishers Inc. and is available from the Princeton Film Center Inc., Princeton, N. J.**

• **Local sections seeking material for technical sessions may be interested in an offer from Bituminous Coal Research Inc. to furnish slide illustrated talks. Called the Combustion Conference Series, lectures offered are: Boiler Plant Operation; Coal Handling Flue-Dust Control; and Smoke Control. BCR can be contacted at 980 Kinnear Road, Columbus 8, Ohio.**

• **Lebanon Steel Foundry has a film called *Steel with a Thousand Qualities*. The 37-min long motion picture is in color accompanied by sound. It tells the story of steel castings from design to final inspection and actual application. Charging, tapping, and pouring operations are shown, along with pattern making, heat treating, and centrifugal casting of stainless steel components. Several animations illustrate what actually occurs in when intergranular corrosion takes place, and how it is overcome through proper heat treatment. The movie is available on a free loan basis from Modern Talking Picture Service Inc., 45 Rockefeller Plaza, New York, or one of its branches.**

Leg Injury Fails to Stop President Reinartz

Leo F. Reinartz, AIME President, kept right on going after an injury sustained while attending a meeting of the American Iron & Steel Institute in New York. After an enforced stay at a New York hospital following an operation to correct severely injured muscles and tendons, Mr. Reinartz flew back to Middletown. Once back in Ohio, he set up operations in his home and continued to carry out his Armco duties. Here he dictates to his secretary, Mrs. Betty Maier.

Local Section Changes By Executive Committee

At its meeting on July 26, the AIME Executive Committee approved release of Moore and Hartley Counties, Texas, from the Panhandle to the Hugoton Local Section. Carson County, Texas, was added to the area of the Panhandle Section. A request for recognition of the New York Petroleum Section was approved, subject to agreement by the executive committee of the New York Section and the working out of arrangements involving its cooperative functions. The new Section would include the five counties comprising New York City (New York, Bronx, Kings, Queens, and Richmond); Nassau and Suffolk Counties on Long Island; Rockland, Orange, Putnam, and Westchester Counties in New York; and Bergen, Essex, Hudson, Middlesex, Monmouth, Passaic, Morris, Somerset, Sussex, and Union Counties in New Jersey.

1954 AIME Budget Reviewed

The AIME budget for 1954 was carefully reviewed at the July 26 meeting of the Executive and Finance Committees in the light of actual results for the first six months of the year. No change was thought necessary in the overall items for Income except that for advertising, which was reduced from $218,000 to $217,000. In the Expense category, Technical Divisions was raised from $68,500 to $69,000; Special Membership Activity from $7000 to $9000; cost of Journals from $310,300 to $314,300; and cost of Transactions Supplement reduced from $18,000 to $13,000. The Income budget does not include any money to be raised outside for publishing metals research papers, which will remain segregated until a special appropriation for its use is voted. The revised budget indicates a deficit for the year of $1300.

"Porphyry Coppers" Revision Planned

A. B. Parsons, former Secretary of the AIME and author of *The Porphyry Coppers*, published in 1933, is now bringing the book up to date. As before, the Rocky Mountain Income Fund is underwriting the volume, and the Executive and Finance Committees of the Institute have approved an expenditure of $7500 for the purpose. A book of some 180 pages is contemplated. The history of the 12 properties covered in the earlier book will be brought up to date, and the newly developed properties in North and South America will be treated in much the same way as before. Engineering and technologic progress of the last quarter century as it relates to the porphyries will be summarized.

Personals

John D. Noll has accepted a position as engineer with the Public Service Co. of Colorado, in Denver.

W. B. Mather, chairman of the mineral technology dept., Southwest Research Institute of San Antonio, has returned to the U. S. after spending four months studying phosphate deposits in Brazil.

Edgar E. Wrege has been named leader of the newly created experimental engineering section of the research & development dept., American Viscose Corp., Philadelphia. Mr. Wrege will be responsible for the development of new machinery and for the design and operation of various corporation pilot plants. He was formerly manager of International Minerals & Chemical Corp.'s experiment station in Mulberry, Fla.

George L. Read has been appointed Canadian sales manager for Bucyrus-Erie Co. He takes over responsibility for the sales of all company products, except water and oil well drills, in all Canadian provinces east of and including Saskatchewan. Mr. Read joined Bucyrus-Erie's export sales dept. in 1945 and has traveled extensively over the world in his capacity as a sales engineer.

Philip P. Powers, who was with Northern Peru Mining & Smelting Co., Tacna, Peru, is now with Dulaney Mining Co., Grand Junction, Colo.

COOPER H. WAYMAN

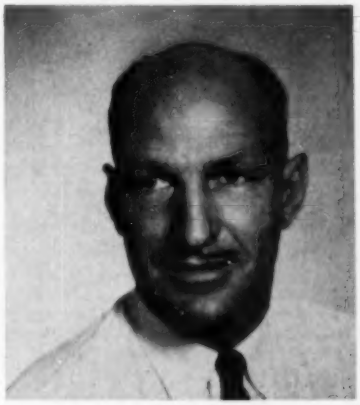
Cooper H. Wayman has resigned his position with U. S. Steel Corp. as research petrographer and is now research assistant at MIT doing graduate work in the dept. of geology & geophysics. Mr. Wayman, who recently received an M.S. degree from the University of Pittsburgh, has worked as a geologist at Lone Star Steel Co., Lone Star, Texas, and American Agricultural Chemical Co., Pierce, Fla.

Chen-Siang Chang, mineral engineer, is with Chemical Construction Corp., New York.

John W. Gabelman has resigned as geologist with American Smelting & Refining Co., Salt Lake City, to accept a position as district geologist with the Atomic Energy Commission, Grand Junction, Colo.

Albert Perry Mason is mining engineer for McLain Fire Brick Co., Div. of the H. K. Porter Co. Inc., Pittsburgh.

C. P. Keegel has resigned as manager for the Cuban interests of Basic Refractories Inc. and as president of Minera Ito S.A. He is now doing mining and metallurgical consultation in Las Vegas, Nev.



J. CHRISTIE

J. Christie was recently transferred from the Nkana mine, Rhokana Corp. Ltd. to Bancroft mine, Bancroft, Northern Rhodesia, as underground manager. Diamond drilling at Bancroft is being continued to increase the present ore reserves of over 89 million tons of 3½ pct copper ore.

William E. Horst has joined the Foote Mineral Co. research & development dept., Philadelphia, as a metallurgical engineer. A graduate of the Missouri School of Mines, Mr. Horst was with U.S. Smelting Refining & Mining Co. and the U.S. Army Engineers from 1952 to 1954.

Edmund McCarthy has been appointed consulting engineer for the New England Div., Pocahontas Fuel Co., coal producers and operators of deep-water coal and oil terminals in New England. Mr. McCarthy has been fuel engineer for the Fairmont Coal Bureau, with the Philadelphia & Reading Coal & Iron Co., test engineer for the New York Edison Co., and since 1948 consulting engineer for the Pittston Co., New York.

Adrian E. Albrethsen is now an assayer in the laboratory of the Sullivan Mining Co.'s zinc plant at Kellogg, Idaho.

M. L. SHOME

M. L. Shome is chief mining engineer and member-secretary, Indian Government Coal Board, Calcutta.

Warren M. Mahan, metallurgist, after completion of work at the U. S. Bureau of Mines alumina plant at Laramie, Wyo., has been transferred to the Pyrometallurgical Branch, Pittsburgh.

J. B. Campbell has joined the staff of Haile Mines Inc., Henderson, Nev. Mr. Campbell is research chemist for the company.

John A. Engstrom, formerly unit superintendent at Topia, Durango, Mexico, has been transferred to Avalos, Zacatecas, as manager of the Avalos unit of the Cia. Minera de Peñoles S. A.. Peñoles is a Mexican subsidiary of the American Metal Co.

G. D. Winans, mining engineer, is with Banner Mining Co., Tucson, Ariz.

Jack Dankowitz, formerly general superintendent Metabol Ltda., Oruro, Bolivia, is plant superintendent, Samuel Greenfield Co., Buffalo.

James E. Morgan, Jr., geologist, is with Uranium Prospectors Co. Ltd., Grand Junction, Colo. He was with the AEC.

Pierre Delaitre, who was with United Nations in New York, is now in the Near East with the UN's TAA Mission, Ministry of Economy, Amman, Jordon.

Wallace W. Muehl is chief engineer, Franklin Baker Co., subsidiary of General Foods Corp., Manila, P. I. He was district engineer, Link-Belt Co., Pittsburgh.

Personals

J. Henry Schindler, Jr., has been named manager of export sales of explosives for Hercules Powder Co. with headquarters in New York. He succeeds **J. R. St. Clair** who has retired after 35 years service with Hercules. Mr. Schindler was recently called to Panama to make recommendations on the use of explosives to eliminate the crack that occurred at the Gaillard Cut of the Panama Canal. He joined Hercules Powder Co. in 1939, following six years experience in the coal industry.

Elmer R. Kaiser has been appointed new director of research for the American Society of Heating & Ventilating Engineers. He will assume his new duties at the Society Research Laboratory, Cleveland, about September 1. Mr. Kaiser has been actively engaged in research work, particularly in the field of fuels, and during the last 20 years has served on the staff of Battelle Memorial Institute, and with Bituminous Coal Research as assistant to the president, assistant director of research, general manager of BCR Products Inc., and associate director of research in charge of BCR Laboratory at Columbus, Ohio.

JAMES R. GARVEY

James R. Garvey has been appointed to succeed Elmer R. Kaiser as assistant director of research, in charge of the Columbus branch office and laboratory, for Bituminous Coal Research Inc. He will also serve as general manager of BCR Products Inc. Mr. Garvey joined BCR in 1946 as development engineer on design and development of residential heating equipment.

Joseph D. Meyers is advertising assistant, Wallace & Tiernan, Belleville, N. J. He was with the Oregon State Highway Dept., Portland.

Bradford P. Edgerton has graduated from Michigan College of Mining & Technology and is employed by the Link-Belt Co., Chicago.

J. B. Tyrrell has resigned as president of Kirkland Lake Gold Mining Co. Ltd. at the age of 95. Succeeding him as head of the company is **V. H. Emery,** formerly vice president and managing director. **W. S. Walton** has been named vice president and **N. S. Beaton,** formerly assistant managing director, has been elected managing director. Mr. Tyrrell, who has been president of Kirkland Lake Gold Mining Co. for the past 23 years, remains a director of the company. In 1881 he joined the staff of the Geological Survey of Canada and explored western and northern Canada. He resigned in 1898 and started in business for himself. Mr. Tyrrell has been a member of AIME since 1899 and may well be the Institute's oldest member. He is the holder of many awards, including the Woleston Medal from the Geological Society of London and an engineering achievement award recently presented to him by the Engineering Institute of Ontario.

L. J. Rohl has been appointed to the newly created position of chief metallurgical engineer, U. S. Steel Corp., N. Y. Succeeding Mr. Rohl as chief metallurgical engineer, operations—steel, is **R. W. Simon.** Mr. Simon joined U. S. Steel in 1927 as a metallurgical assistant at Homestead Works and Mr. Rohl joined the company at South Works, Chicago, in 1917. In 1953 Mr. Rohl spent several months in Europe as consultant for the European Steel Industry.

F. A. Hames has become chairman of the dept. of metallurgical engineering, Montana School of Mines, Butte, with the rank of full professor.

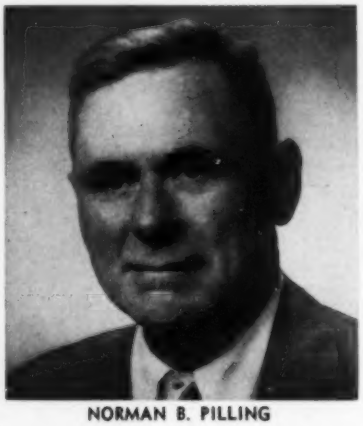
Harold N. Hicks is superintendent, Truax Traer Coal Co., Ceredo Preparation Plant, Ceredo, W. Va.

Ben B. Chomiak, formerly with Cia. Minera Asarco S.A., Parral, Chih., Mexico, is with Tsumeb Corp., Tsumeb, South West Africa.

Thor Gjelsteen is now employed as a mining engineer with the Vanadium Corp. of America, Naturita, Colo. Mr. Gjelsteen, who graduated from the Missouri School of Mines and Metallurgy in 1953, was with Geophysical Service Inc., Dallas.

J. D. Deery, who was chief engineer, West Virginia Coal & Coke Corp., Omar, W. Va., is chief engineer, Ethel Chilton Mines Inc., Ethel, W. Va.

Charles F. Stanley, who was assistant superintendent of the Carlton Mill, Golden Cycle Corp., Victor, Colo., is now production engineer, Gates Rubber Co., Denver.



NORMAN B. PILLING

Norman B. Pilling, director since 1939 of the Bayonne, N. J., Research Laboratory, International Nickel Co. Inc., has been appointed assistant to the vice president, manager, Development & Research Div. in New York. He is the author of many technical papers and more than 80 patents have been issued on his inventions in the U. S. and abroad. Succeeding Mr. Pilling as head of the laboratory is **W. Andrew Wesley,** assistant director since 1939. Mr. Wesley is the author of 35 publications and 16 patents have been issued for his inventions. **John T. Eash,** metallurgical supervisor and head of the ferrous castings section of the laboratory, becomes assistant manager. Mr. Eash became associated with Inco in 1931. He also has written numerous technical papers and holds several patents

W. ANDREW WESLEY

J. Brian Eby of Houston, former chief of the Shell Oil Co.'s Gulf Coast geophysical dept. and an independent consulting geologist for many years, has been named a director of Texas International Sulphur Co.

Personals

W. D. Hubler has left Mediterranean Mines Inc., Athens, Greece, and is with Quebec Metallurgical Industries, Ottawa, Ont.

Anton Gray, vice president of Kennecott Copper Corp., New York, resigned August 1 because of ill health. Mr. Gray will establish his home in the west of England, retiring from all professional work.

Victor Barua R., geologist, has been transferred from the Toquepala to the Chilete unit of Northern Peru Mining & Smelting Co.

Rufus A. Breland is safety engineer, Freeport Sulphur Co., Port Sulphur, La. He was with Woodward Iron Co., Birmingham.

Clayton D. Grover, vice president, Whitehead Metal Products Co. Inc., has succeeded **Thomas M. Bohen** as president. Mr. Bohen, now chairman of the board, became president in 1939. Mr. Grover joined International Nickel Co. Inc. at the company's Huntington Works physical laboratory, Huntington, W. Va., in 1925. He was transferred in 1927 to the Boston office of Whitehead Metal Products Co. Inc., an Inco subsidiary. Mr. Grover, a director of Whitehead since 1949, is the author of several technical publications.

S. R. ZIMMERLEY

S. R. Zimmerley is director of Kennecott's new $1.25 million Research Center, which was dedicated August 13 at the University of Utah campus, Salt Lake City. Mr. Zimmerley is research director of Kennecott's four Western Mining Divisions and former chief, Metallurgical Branch, Region IV, U. S. Bureau of Mines.

W. P. Hewitt, geologist, American Smelting & Refining Co., who was with the Mexican Div., El Paso, Texas, is now with the western mining dept., Salt Lake City.

Thomas W. Young is shift boss, Anaconda Copper Mining Co., Butte, Mont.

PATRICK H. O'NEILL

Patrick H. O'Neill is assistant vice president, South American Gold & Platinum Co., New York. He was chief engineer, Cia. Mineral Choco Pacifico, Cali, Colombia, and before that dredge superintendent, Fairbanks dept., U. S. Smelting Refining & Mining, Alaska.

Elvin M. Hoffman is with Western Geophysical Co., Albuquerque, N. M.

Rev. James B. Macelwane, dean of the Institute of Technology, St. Louis University, has been appointed by the State Dept. to head the official voting delegation of the U. S. to the 10th general assembly of the International Union of Geophysics & Geodesy in Rome September 14 to 25.

William Michael Romischer, mining engineer, is with the U. S. Bureau of Mines, Seattle. He was with the Anthracite Flood-Prevention Section, Wilkes-Barre, Pa.

Clay T. Smith, head of the geology dept., New Mexico Institute of Mining & Technology, Socorro, is the author of a 40-page report on the Thoreau Quadrangle recently published by New Mexico Bureau of Mines & Mineral Resources. *(See page 859.)*

Chester M. F. Peters completed his contract as resident engineer for Knappen, Tippetts, Abbett Inc., Rangoon, Burma and is now living in Salt Lake City. Mr. Peters is engaged in consulting work for various firms operating on the Colorado Plateau and in Nevada.

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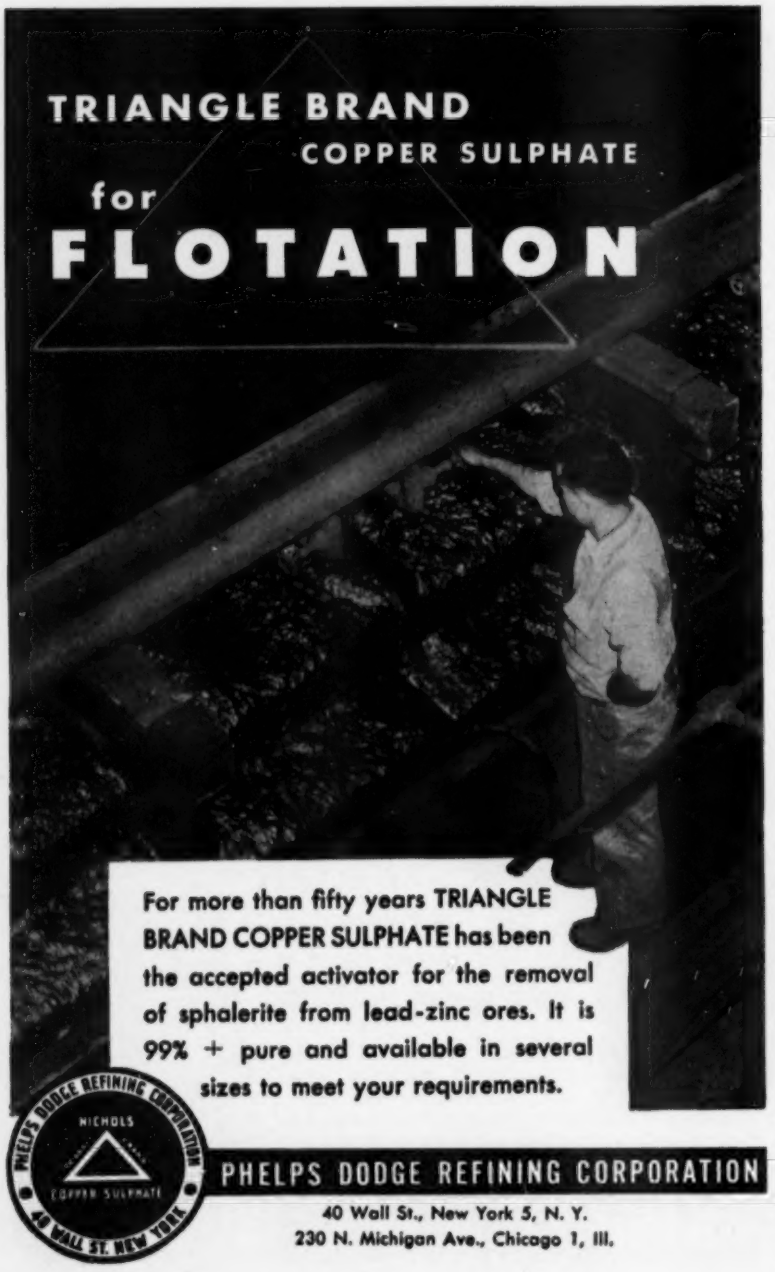
Personals

Edward S. Frohling is mill superintendent for St. Lawrence Fluorspar Inc., Wilmington, Del. He was technical representative, Western Machinery Co., Birmingham.

James F. McDivitt is scientific officer, Mineral Resources Div., Mines Branch, Dept. of Mines & Technical Surveys, Ottawa. He was assistant professor of geology, University of Idaho, Moscow.

Wayne R. Dolezal is employed as a geologist with Navajo Uranium Div., Kerr-McGee Oil Industries, Inc., Shiprock, N. M.

Vernon Severt Severtson, for the past four years a field engineer for the Eimco Corp., Salt Lake City, working out of the Chicago office, is now associated with U. S. Gypsum Co., Sweetwater, Texas.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R. M. Ingels is now an engineer with the Los Angeles Air Pollution Control District.

W. C. RUECKEL

W. C. Rueckel and **E. T. Larsen** have been named vice presidents of Henry J. Kaiser Co., Oakland, Calif., parent company of the Kaiser group of industries. Mr. Rueckel, formerly a division manager for Kaiser Engineers, has been made manager of development & sales. Mr. Larsen as manager of engineering will be responsible for all engineering activities for Kaiser Engineers, a division of the parent firm.

John F. Wells, recently graduated from MIT, is a lieutenant in the U. S. Marine Corps.

Richard A. Mullins, chief chemist, Ayrshire Collieries Corp., Danville, Ill., is now with the Enos Coal Mining Co., Oakland City, Ind.

R. EMMET DOHERTY

R. Emmet Doherty, dust control engineer, Anthracite Institute, Wilkes-Barre, Pa., is now a consulting industrial dust engineer with offices in Kingston, Pa.

Obituaries

James Colquhoun (Member 1898) died June 17, 1954 in Victoria, B. C. He was at one time president of the Arizona Copper Co. and one of the pioneers in porphyry copper development. Born in Holytown, Lanarkshire, Scotland, in 1857, Mr. Colquhoun went to Clifton, Ariz., in the early 1880's as general superintendent of the Scottish-owned Arizona Copper Co., which was subsequently sold to Phelps Dodge Corp. He became president of Arizona Copper in the early 90's. According to *A History of Phelps Dodge* by R. G. Cleland, the fortunes of the Arizona Copper Co. began to mend almost as soon as Mr. Colquhoun took charge. The discovery of new orebodies led to the erection of a leaching plant and he did pioneer work on this process. "A remarkable metallurgist and engineer," he was also greatly interested in the public schools of the district.

As chairman of the Caucasus Copper Co., Mr. Colquhoun went to Russia and was caught there during the revolution. He described his experiences from 1916 to 1918 in a privately printed book, *Adventures in Red Russia*. Other books by him include *Early History of the Clifton-Morenci District* and *Clifton-Morenci Mining Industry*. For many years after retirement, Mr. Colquhoun, a great lover of cricket, spent his summers in England and wintered in California, but his last years were spent in Victoria, B. C. He was a Legion of Honor Member of AIME.

Alfred J. Christenson (Member 1948) died July 1, 1954. He was for many years superintendent for Republic Steel Corp. in Crystal Falls and Ironwood, Mich. Mr. Christenson was born in Madelia, Minn., in 1891 and received his E.M. from the University of Minnesota in 1915. His early experience was gained as assistant mining engineer for Arthur Iron Mining Co., Chisholm, Minn., and he was later a shift boss for the Lutonia mine, Jones & Laughlin Co., Hibbing, Minn. In 1920 he went to work for the Corrigan McKinney Steel Co., Crystal Falls, and when he left this company in 1929 to go with E. J. Longyear Co. in Minneapolis, he was chief engineer and superintendent. Mr. Christenson also worked as an engineer with the Minnesota State Highway Dept.

John A. Savage (Member 1946) died June 14, 1954. He was 70 years old. Mr. Savage was a mining engineer and had been since 1914 owner of John A. Savage & Co., a Duluth iron mining and lake shipping company. After receiving his Ph.B. from Yale in 1904, he worked with Harbison-Walker Refractories Co. in Pittsburgh until 1907. For the next seven years Mr. Savage was general superintendent and general manager for Shenango Furnace Co., Hibbing, Minn.

Kurt Albert Spohr (Member 1946) died suddenly of a heart attack on May 9, 1954 at his home in Scarsdale, N. Y. He was assistant secretary of Philipp Bros. Inc., New York. Mr. Spohr was born in 1904 in Frankfurt, Germany, and after studying at the Staatsakademie in Berlin, received his early training with Metallgesellschaft A.S. In 1927 he went to Leadville, Colo., to work for the Ore & Chemical Corp. and later became general manager. Mr. Spohr left this company six years ago to become associated with Philipp Bros. Inc.

An Appreciation of
George Theodore Walters
by
T. D. Guernsey

George Theodore Walters (Member 1937) died in Johannesburg on May 26, 1954.

G. T. Walters was born in Scarsdale, N. Y., on Aug. 20, 1902. At the age of 12 he accompanied his parents to Canada and continued his primary schooling in Alberta. In 1921 he entered the University of Alberta where he specialized in geology and received the degree of B.Sc. in 1925.

Necrology

Date Elected	Name	Date of Death
1948	Alfred J. Christenson	July 1, 1954
1922	Edward Dixon	June 7, 1954
1890	Lewis E. Dunham	Apr. 14, 1953
1945	James A. Kavenaugh	May 28, 1954
1938	Nathan Landau	June 22, 1953
1943	Thomas W. Pew	Unknown
1938	Edwin L. Ramsey	July 23, 1954
1946	John A. Savage	June 14, 1954
1919	Harry A. Schwartz	July 25, 1954

In 1926 Walters began post graduate studies at the University of Toronto but interrupted these for work in Africa. In 1927 he was employed as field geologist for one of the concession companies at the beginning of an extensive prospecting campaign in Northern Rhodesia under the direction of J. A. Bancroft.

Walters' association with Dr. Bancroft lasted for 27 years during which time he did important field work in many parts of Northern Rhodesia and was resident geologist at the Nchanga, Nkana, and Kansanshi copper mines. In the years 1944 to 1951 he worked on diamond deposits, first on the Cape coast and later as field manager of a prospecting company in the northern part of South West Africa.

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his observations and conclusions, "One Horse," as he will be remembered by his friends in Africa and America, was an ideal colleague and companion. Of a somewhat shy and retiring temperament, he had a fund of wit and humor for all occasions and difficulties, and as a consequence, a wide circle of friends who will deeply regret his death. He is survived by his wife, Jean Rosaleah Walters, to whom he was married in January 1937.

Proposed for Membership

MINING BRANCH, AIME

Total AIME membership on July 31, 1954 was 21,160; in addition 1714 Student Associates were enrolled.

ADMISSIONS COMMITTEE

O. B. J. Fraser, Chairman; R. B. Caples, Vice-Chairman; F. A. Ayer, A. C. Brinker, R. H. Dickson, Max Gensamer, Ivan A. Given, Fred W. Hanson, T. D. Jones, Sidney Rolle, J. H. Scaff, John T. Sherman, F. T. Sisco, Frank T. Weems, R. L. Ziegfeld.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

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Morenci—McFarland, William D. (J)
Superior—Gould, Walter R. (J)
Tucson—Blois, Robert W. (J)
Tucson—Smith, Sigmund L. (R. C/S—J-M)
Arkansas
Bauxite—Cross, Robert C. (M)
California
Atherton—Cooper, Robert J. (R. M)
Bishop—Laczynski, Edward M. (R. C/S—S-J)
Los Angeles—Carlin, James J. (A)
Los Angeles—Slichter, Louis B. (R. M)
San Gabriel—Godfrey, Ralph G. (R. C/S—S-M)
Torrance—Reinhart, Jack W. (R. C/S—S-M)
Colorado
Denver—Holmer, Ralph C. (R. C/S—J-M)
Denver—Landon, Robert E. (R. M)
Gilman—Lindquist, John T. (R. C/S—S-J)
Longmont—Crow, Walter L. (R. C/S—S-M)
Idaho
Soda Springs—Crouse, Russell H. (J-M)
Illinois
Chicago—Hogreff, William E. (A)
East St. Louis—Stewart, Thomas J. (M)
Urbana—Frye, John C. (M)
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White Pine—Robison, Joe T. (R. C/S—S-M)
Minnesota
Aurora—Bell, Robert W. (R. C/S—S-M)
Bovey—Thomte, Walter L. (M)
Duluth—Higgins, Raymond J. (M)
New Jersey
Mountain Lakes—Reed, George G., Jr. (A)
Pennington—Widmer, Kemble (M)
New Mexico
Alburquerque—Hostetter, Glenn E. (A)
Albuquerque—Perhac, Ralph M. (J-M)
New York
Elmhurst, L. I.—DeSanctis, Helen E. (M)
New York—Hohmann, Harry E. (J)
Pennsylvania
Jenkintown—Bottorf, Robert G. (A)
Pottsville-Geho, Charles H. (M)
South Dakota
Lead—Swent, Langan W. (C/S—A-M)
Trojan—Stoehr, Richard J. (R. C/S—S-J)
Utah
Salt Lake City—Birch, Lochinvar B. (R. C/S—S-M)
West Virginia
Gary—Egan, Howard N. (M)
Australia
Alexandria, NSW—Witt, Erik H. (M)
Northern Rhodesia
Noola—Baillie, John E. (M)
Pakistan
Baluchistan—Karim, Inayat (M)
Peru
Arequipa—Baldwin, Robert W. (A)
Lima—del Aguila, Hernan (M)
Lima—Loret de Mola, Carlos (M)
Union of South Africa
Nahoon, East London—Abbott, Donovan W. (J)

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Coming Events

Sept. 20-24, American Mining Congress, Civic Auditorium, San Francisco.

Sept. 23-24, Central Pennsylvania Coal Producers Assn., annual meeting, Bedford Springs Hotel, Bedford, Pa.

Sept. 24, AIME, Minerals Beneficiation Div., fall meeting, Fairmont Hotel, San Francisco.

Sept. 25, U. S. Bureau of Mines, dedication of Rare & Precious Metals Experiment Station, Reno, Nev. 10:30 am.

Sept. 26-29, American Society of Mechanical Engineers, Petroleum Mechanical Engrg. Conference, Hotel Statler, Los Angeles.

Sept. 30, AIME Utah Section, stag; cocktails, dinner, smoker, 7:00 pm Newhouse Hotel.

Oct. 5-9, AIME Industrial Minerals Div., fall meeting, Whiteface Inn, Lake Placid, N. Y.

Oct. 14-16, New Mexico Mining Assn. and El Paso International Mining Assn., joint convention, Carlsbad, N. M.

Oct. 14-16, Drilling Symposium, University of Minnesota, Minneapolis.

Oct. 17-20, AIME Petroleum Branch, Plaza Hotel, San Antonio.

Oct. 18, AIME Columbia Section, Spokane, Wash.

Oct. 18-22, American Society of Civil Engineers, annual meeting, Hotel Statler, New York.

Oct. 18-22, National Safety Congress and Exposition, Chicago, Ill.

Oct. 26, Assn. of Consulting Chemists and Chemical Engineers Inc., annual symposium and banquet, Hotel Belmont Plaza, New York.

Oct. 27-29, Clay Mineral Technology, Third National Clay Minerals Conference, Rice Institute, Houston.

Oct. 28-29, Engineers' Council for Professional Development, Hotel Alms, Cincinnati.

Oct. 28-29, AIME, ASME Fuels Conference, William Penn Hotel, Pittsburgh.

Oct. 29, AIME, NOHC and Pittsburgh Local Section, off-the-record meeting, William Penn Hotel, Pittsburgh.

Oct. 29-30, AIME, Industrial Minerals Div., Rocky Mountain Region Industrial Minerals Conference, Salt Lake City. Registration Oct. 28.

Oct. 30, AIME, Utah Section, annual fall cocktail party, dinner dance, 7:00 pm, Newhouse Hotel, Salt Lake City.

Nov. 1-3, AIME, Institute of Metals Div., fall meeting, Hotel Morrison, Chicago.

Nov. 1-3, Geological Society of America and Associated Societies, Statler and Biltmore hotels, Los Angeles.

Nov. 5-6, AIME National Open Hearth Conference, Southern Ohio Section, Deshler-Hilton Hotel, Columbus, Ohio.

Nov. 5-6, AIME Central Appalachian Section, annual meeting, Homestead, Hot Springs, Va. Joint meeting with West Virginia Coal Mining Institute.

Nov. 8-11, American Petroleum Institute, 34th annual meeting, Conrad Hilton Hotel and Palmer House, Chicago.

Nov. 12, Illinois Mining Institute, Hotel Abraham Lincoln, Springfield, Ill.

Nov. 18, AIME, Utah Local Section, joint meeting with Intermountain Assn. of Petroleum Geologists, 8:00 pm, Newhouse Hotel, Salt Lake City.

Nov. 18, American Mining Congress, Coal Div., Wm. Penn Hotel, Pittsburgh.

Nov. 18-19, Society of Exploration Geophysicists, 8th annual Midwestern meeting, Adolphus Hotel, Dallas. Registration Nov. 17.

Nov. 28-Dec. 3, American Society of Mechanical Engineers, annual meeting, Hotel Statler, New York.

Dec. 1-4, AIME Electric Furnace Conference, William Penn Hotel, Pittsburgh.

Dec. 12-15, American Institute of Chemical Engineers, annual meeting, Statler Hotel, New York.

Dec. 26-31, American Assn. for the Advancement of Science, national meeting, University of California, Berkeley, Calif.

Feb. 14-17, 1955, AIME, Annual Meeting, Conrad Hilton Hotel, Chicago.

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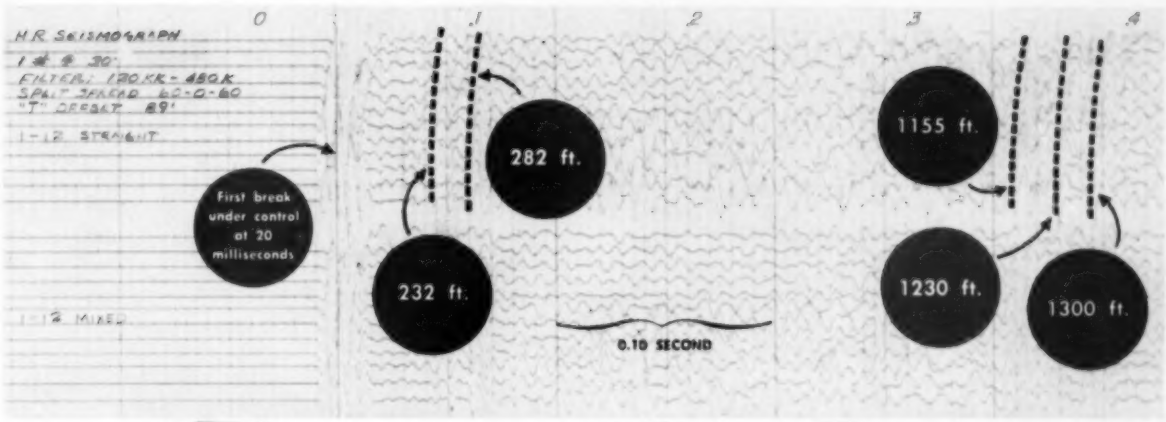

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